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# SATELLITE SERVICES SYSTEM ANALYSIS STUDY

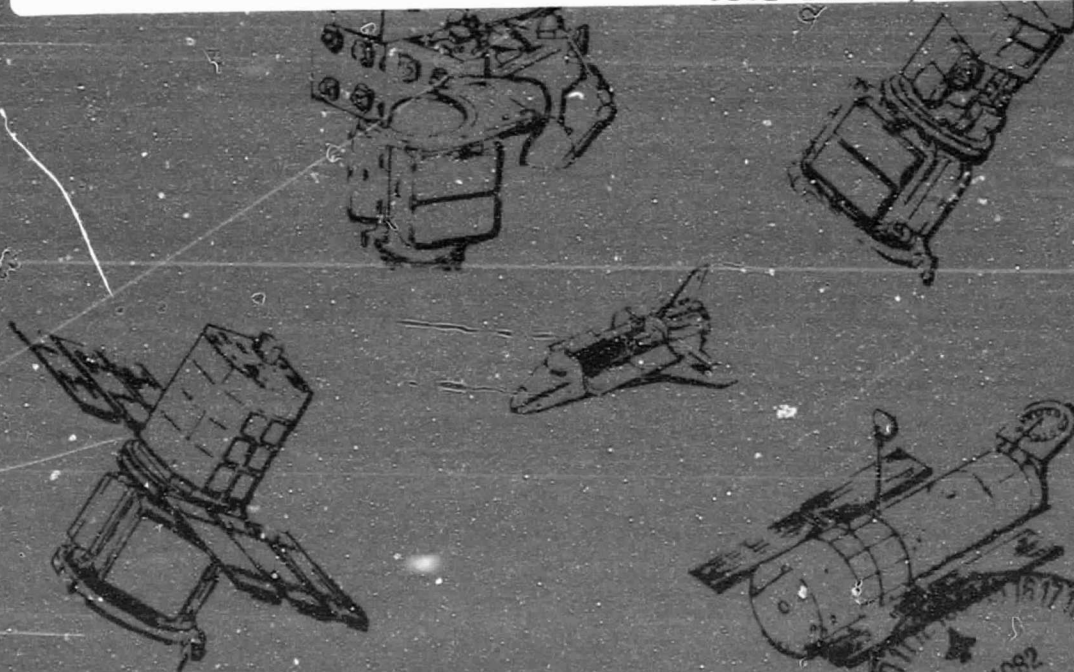
volume 2 — satellite  
& services user model

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GRUMMAN AEROSPACE CORPORATION



# **SATELLITE SERVICES SYSTEM ANALYSIS STUDY**

**volume 2 — satellite  
& services user model**

prepared for  
National Aeronautics and Space Administration  
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## **FOREWORD**

The Satellite Services System Analysis Study (SSSAS) was conducted for the Lyndon B. Johnson Space Center and directed by Contracting Officer's Representatives (COR), Mssrs. Reuben Taylor and Gordon Rysavy. Grumman Aerospace Corporation's study manager was Mr. John Mockovciak Jr.

This final report is presented in seven volumes:

Volume 1 - Executive Summary

Volume 2 - Satellite and Services User Model

Volume 2A - Satellite and Services User Model - Appendix

Volume 3 - Service Equipment Requirements

Volume 3A - Service Equipment Requirements - Appendix

Volume 4 - Service Equipment Concepts

Volume 5 - Programmatic

Volume 2 contains an analysis of satellite services needs, presents the Satellite and Services User Model (S/SUM) developed for the study, and identifies the reference satellites used for service equipment concept development. The Appendices contain an initial/updated Satellite User Model listing and document the assessment of service needs/extent of manned, remote, or automated involvement.



## **ACRONYMS**

**Abbreviations and acronyms used frequently throughout the Satellite Services System Analysis Study (SSSAS) are defined as follows:**

**ACS - Attitude Control System**  
**AFD - Aft Flight Deck**  
**ASM - All Sky Monitor**  
**AXAF - Advanced X-Ray Astrophysics Facility**  
**CCTV - Closed Circuit Television**  
**C & DH - Command & Data Handling**  
**C & DL - Command & Data Link**  
**C/O - Checkout**  
**DDT&E - Design, Development, Test & Evaluation**  
**DoD - Department of Defense**  
**DOF - Degrees of Freedom**  
**EMU - Extra-Vehicular Mobility Unit**  
**EVA - Extra Vehicular Activity**  
**FSS - Flight Support System**  
**GAC - Grumman Aerospace Corporation**  
**GEO - Geosynchronous Earth Orbit**  
**GRAVSAT - Earth Gravity Field Survey Mission**  
**GRO - Gamma Ray Observatory**  
**GSE - Ground Support Equipment**  
**HEAO - High Energy Astronomy Observatory**  
**HPA - Handling & Positioning Aid**  
**IR - Infrared**

IRAD - Independent Research and Development  
IUS - Inertial Upper Stage  
IVA - Internal Vehicular Activity  
JSC - Johnson Space Center  
KSC - Kennedy Space Center  
LAPC - Large Area Proportional Counter  
LASS - Large Amplitude Space Simulator  
LASSII - Low Altitude Satellite Studies of Ionospheric Irregularities  
LEO - Low Earth Orbit  
LOS - Line-of-Sight  
MDF - Manipulator Development Facility  
MFR - Manipulator Foot Restraint  
MMS - Multimission Modular Spacecraft  
MMU - Manned Maneuvering Unit  
MRV - Manned Reconnaissance Vehicle  
MTV - Maneuverable Television  
NOSS - National Oceanic Satellite System  
OAO - Orbiting Astronomical Observatory  
OBC - Onboard Checkout  
OCC - Operations Control Center  
OCP - Open Cherry Picker  
OMS - Orbital Maneuvering System  
PAM A - Payload Assist Module (type) A  
PAM D - Payload Assist Module (type) D  
PIDA - Payload Installation & Deployment Aid  
PM I/II - MMS Propulsion Module I & II  
POCC - Payload Operations Control Center

**POM - Proximity Operations Module**

**RCS - Reaction Control System**

**RMS - Remote Manipulating System**

**ROM - Rough Order of Magnitude**

**S/C - Spacecraft**

**SE&I - System Engineering & Integration**

**SMM - Solar Maximum Mission**

**SRM - Solid Rocket Motor**

**SSS - Satellite Services System**

**SSSAS - Satellite Services System Analysis Study**

**S/S - Subsystem**

**S/SUM - Satellite and Services User Model**

**STE - Special Test Equipment**

**STS - Space Transportation System**

**TDRS(S) - Tracking & Data Relay Satellite (System)**

**TMS - Teleoperator Maneuvering System**

**TV - Television**

**UARS - Upper Atmospheric Research Satellite**

**UV - Ultraviolet**

**VSS - Versatile Service Stage**

**WBS - Work Breakdown Structure**

**WETF - Weightless Environment Training Facility**

**WIF - Water Immersion Facility.**

**WRU - Work Restraint Unit**

**XTE - X-Ray Timing Explorer**

## 1 - ANALYSIS OF SATELLITE SERVICES NEEDS

This section identifies current and projected satellites for which services may be needed. Service functions potentially needed for each satellite are identified in terms of deployment, examination, retrieval, support, and earth return. The potential extent of direct-manned and remote (man-in-the-loop) involvement are also identified, as is the extent of automatic operation. Additionally, the status of object identification information for inactive satellites and space debris is examined.

### 1.1 METHODOLOGY

The approach used to identify potential satellite service needs is shown in Fig. 1-1. A Satellite User Model computer listing was developed which identifies potential satellite programs (through 1993) and their estimated launch dates. Data was obtained from various available unclassified sources to prepare the satellite listing.

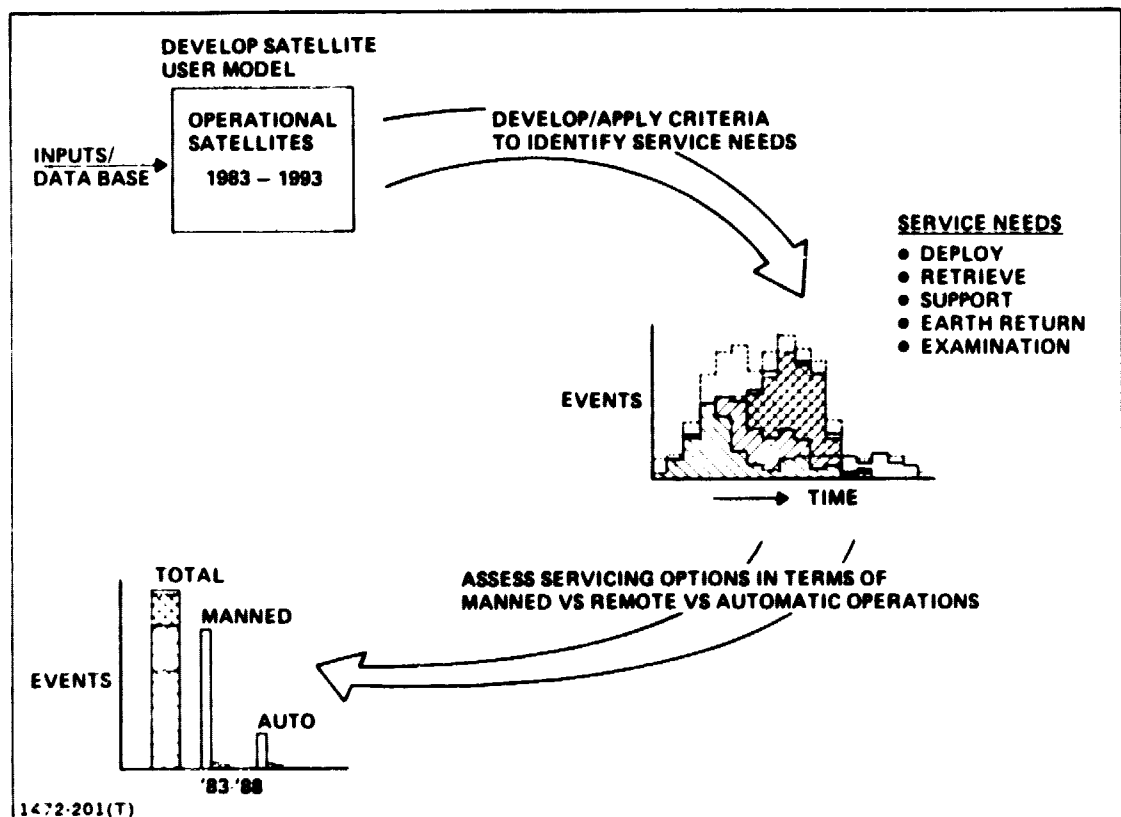


Fig. 1-1 Methodology for Identifying Service Needs

A set of criteria was then developed, with supporting rationale, and was used to assess the need for various satellite services. In conjunction with engineering judgement, the criteria were applied to each of the candidate satellites to identify potentially required service functions. These potential service needs were added to the computer listing and subsequently expressed in terms of histograms to show frequency of service needs as a function of time.

The next step was to address satellite user listings in terms of manned, remote (man-in-the-loop) and/or automated involvement. Again, engineering judgement was applied to establish this identification. This data was also added to the computer listing and then displayed in terms of the number of service events for a five year time interval.

## **1.2 SATELLITE USER MODEL**

A Satellite User Model (SUM) was developed to identify current and potential satellites for which services may be needed. Input sources for developing the SUM included:

- NASA 5-Year Plan (1981 - 1985)
- STS Flight Assignment Baseline
- Battelle Low Energy Mission Model
- OAST Space Systems Technology Model
- DoD Mission Catalog
- NORAD Spacecraft Identification Listing
- Future Planning Documents (e.g., OSTA and OSS)

Each satellite listed in the SUM is classified in one of the following categories:

- ☐ **A** Approved - Missions that have been funded and authorized for implementation
- ☐ **P** Planned - Missions designated by a program office as "new starts" within the next five years
- ☐ **C** Candidate - Missions considered for possible initiation within ten years, but not currently planned as "new starts" within the next five years
- ☐ **O** Opportunity - Potential missions for start beyond ten years and/or those missions of a speculative nature

Definitions of the categories are in consonance with the NASA Space Systems Technology Model.\* The categories identified in the NASA Model are also carried in the SUM. Categorization of other satellites and payloads is based on current information about the program status or, if information was not available, Grumman judgement was employed.

Operational parameters of satellites that are candidates for servicing are shown in the computer program listing illustrated in Fig. 1-2. The SUM reflects more than 220 discrete candidate STS satellite and payload launches through the year 2000; the listing excludes multiple satellite launches, revisits, and retrievals that may be associated with these spacecraft.

SATELLITE	NO.	SPONSOR ORG	CATE- GORY	S/C MASS (kg)	PHYS CHAR.		DELY ORB (km)	FINAL ORB (km)	ORBIT INC (Deg)	LAUNCH SITE	CARRIER	MANIF NUMBER	FILE NUMBER
					LENS (m)	DIA (m)							
ERBS EARTH RAD BUDGET	E 4	OSTA	A	1134	4.00	2.10	296	600	46.00	ETR	MMS	STS 22	282AVN
RCA F	-		A	-	-	-	296	36786	28.50	ETR	SSUS D	STS 24	283AVN
ARABSAT A	-	ARA	A	-	-	-	296	36786	28.50	ETR	SSUS D	STS 24	284AVN
OSS 2	-	OSS	A	-	-	-	296	296	28.50	ETR	OFT PAL	STS 24	285AVN
AT & T 1	-	COM	A	-	-	-	296	296	28.50	ETR	SSUS D	STS 24	286AVN
AMPTC ACT MAG. PART E	S 6	OSS	A	770	1.10	3.00	300	79E	28.50	ETR	SSUS D	STS 26	287STM
SYNCOM IV 2 LEASAT	-	COM	A	1315	4.00	4.10	296	36786	28.50	ETR	UNIQ STA		
SI SPACE TELESCOPE	A 3	OSS	A	11000	13.60	4.30	603						
LUDEF	UI 10	OAST	A	4500	8.10								
PALAPA M/2		INDS											

\*EXCLUDES REVISITS/EARTH RETURN

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> 220  
CANDIDATES

Fig. 1-2 Candidates for Satellite Servicing

Most of the data shown in Fig. 1-2 is self explanatory: Satellite numbers refer to NASA Space System Technology Model designations and the category is, as described, A, P, C or O; orbit inclination refers to the Orbiter launch and/or first satellite inclination, as applicable; the manifest number is taken from NASA's Flight Assignment Manifest dated June 15, 1980. Data sources are identified within the file number as follows:

Code

Source

- NAS NASA STS Mission Model, October 1977

\*Ref: OAST Space System Technology Model, May 1980

<u>Code</u>	<u>Source</u>
● LEP	Low Energy Payload Model, September 1979
● MDC	Mission Data Catalog, October 1979
● FAM	NASA Flight Assignment Manifest, June 1980
● STM	NASA Space Systems Technology Model, May 1980
● AVN	Aviation Week.

The SUM computer listing is documented in Appendix 4 of this volume.

A summary of sponsoring satellite organizations reflected in the Satellite User Model for the years 1981 through 1988 is shown in Fig. 1-3. Within this time period, NASA/NOAA predominates all other sponsors; whereas commercial, DoD, and foreign sponsors are nearly equivalent in overall numbers of satellites.

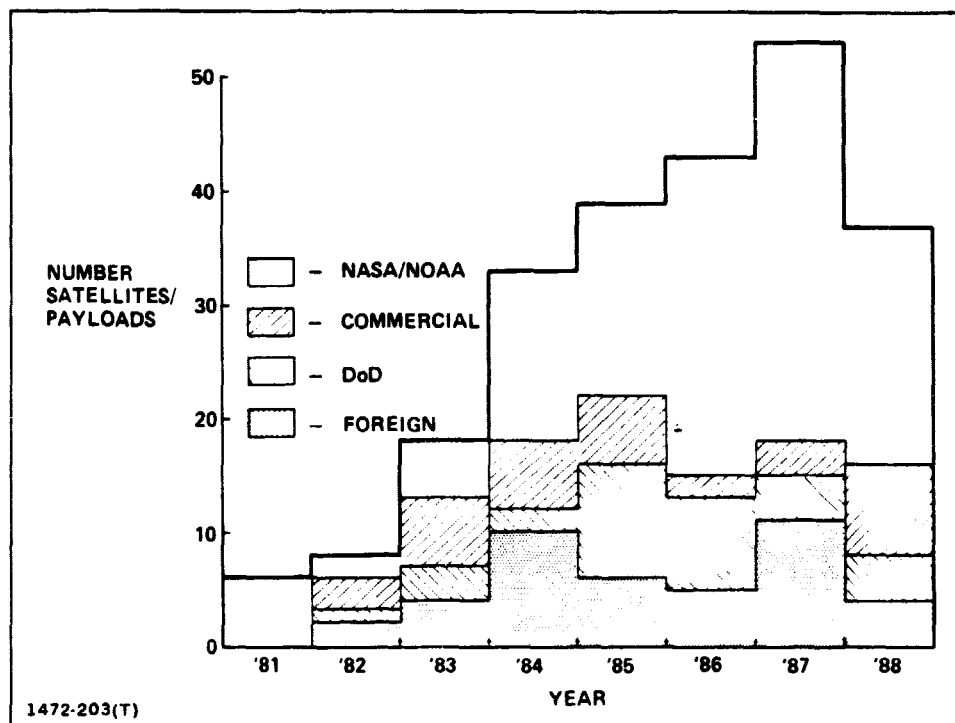


Fig. 1-3 Sponsoring Satellite Organizations

### 1.3 REPRESENTATIVE SERVICING SCENARIOS

Servicing Scenarios were developed for delivery and revisit flight situations. They include:

- Deployment
- Backup Retrieval & Redeployment
- Unscheduled Maintenance & Repair
- Planned Maintenance & Repair.

The representative scenarios were developed to identify and understand the extent of service functions attributed to nominal Orbiter service missions, and to support the analysis of potential satellite service needs (Refer to Section 1.4).

The identification of potential service needs for satellites and payloads in the SUM has considered both nominal and contingency modes of operation. For example, as illustrated in the deployment scenario of Fig. 1-4, a satellite launched by the STS is a candidate for four of the five top-level service functions (lacking only the retrieval service function):

- Examination
  - Checkout
  - Repair
  - Deployment
  - Earth Return.
- } Support

All satellites and/or payloads could benefit from checkout prior to deployment. Fidelity of checkout, however, depends on subsequent satellite events and satellite design features. If checkout reveals discrepancies from nominal operation, contingency operations must be implemented. This would require further examination of the satellite to determine if repair can be implemented on-orbit during the same flight, or on a subsequent flight. For example, a determination might be made that the best course of action would be to return the satellite to earth for repair.

A backup retrieve/redeployment scenario encompasses all top-level service functions (See Fig. 1-4). Service functions are illustrated that might be required shortly after a satellite is deployed and encounters anomalies in achieving operational status. It is assumed that the Orbiter is in a stand-off mode and in the immediate vicinity of the



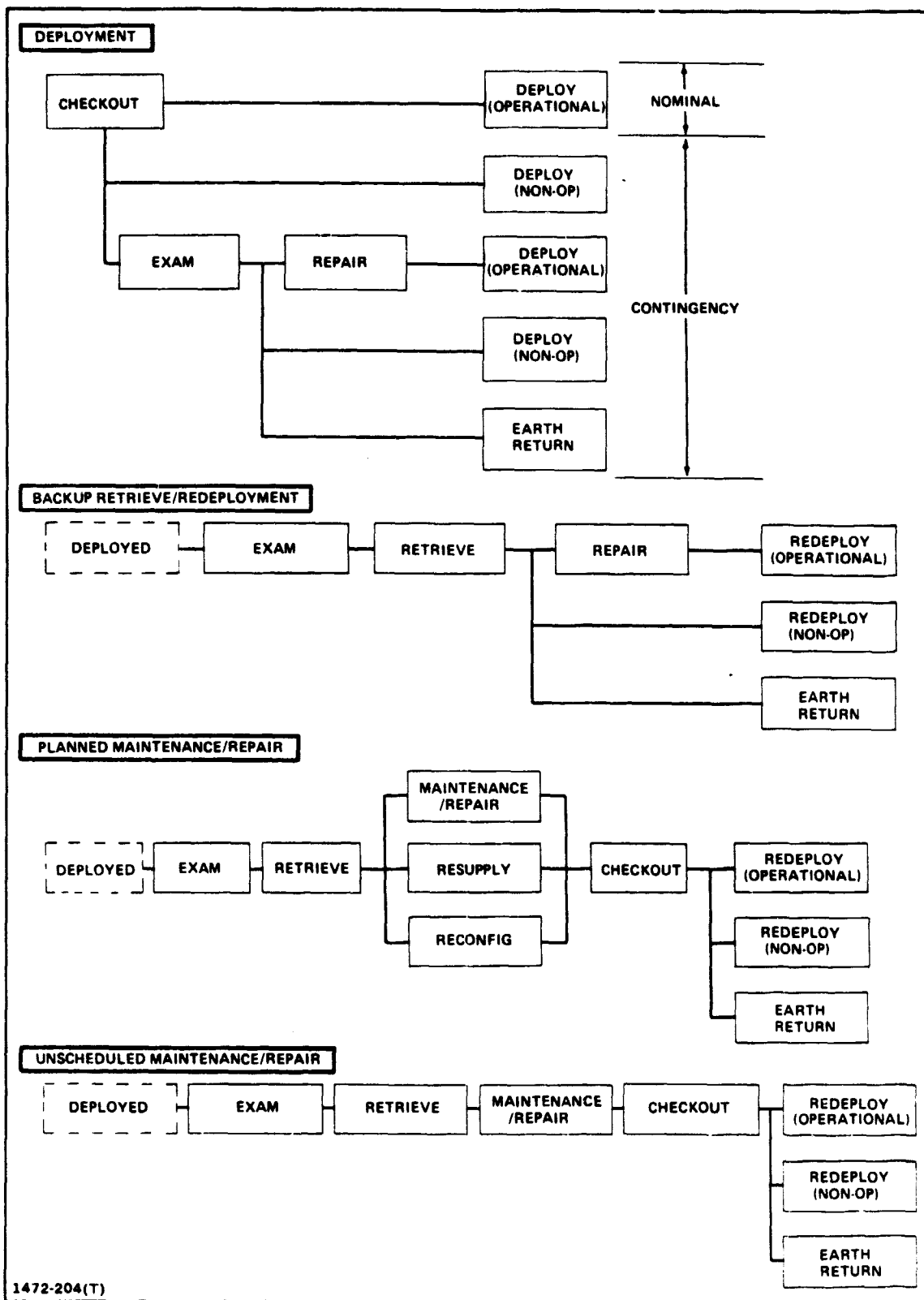


Fig. 1-4 Representative Servicing Scenarios

satellite. Depending on the anomaly, the satellite is examined, retrieved, repaired, and redeployed as it would be in a nominal operation. Or, if the repair is not possible on-orbit, the satellite is retrieved and returned to earth for ground repair. A third option is to re-deploy the satellite for on-orbit storage and possible repair in subsequent Orbiter flights.

Figure 1-4 also shows the servicing function sequence required for planned Orbiter visits to satellites for nominal support servicing. The sequence identifies all service functions through checkout, and the alternatives available if satisfactory checkout is not accomplished.

In the case of LEO satellites that are in an orbit not directly reachable by the Orbiter, examination and retrieval is accomplished by a maneuvering propulsion stage which returns the satellite to the immediate vicinity of the Orbiter for servicing.

Also shown in Fig. 1-4, are the servicing functions associated with an unscheduled maintenance/repair scenario. It is assumed that a satellite anomaly is experienced prior to mission completion, and that an Orbiter revisit is required to repair the premature failure. The Orbiter is maneuvered to the immediate vicinity of the satellite, the satellite is examined and retrieved, the intended repair is accomplished, and the satellite is redeployed for mission continuance. Variations include returning the satellite to earth if effective repair cannot be accomplished, or redeploying the satellite for on-orbit storage and subsequent repair visits.

#### 1.4 POTENTIAL SERVICE NEEDS

Each candidate satellite in the SUM (Refer to Appendix A) has been addressed in terms of known or potential service needs.

##### 1.4.1 Criteria for Identifying Service Needs

It is recognized that the justification or need for a service function must come from the satellite program involved and the service function's effectiveness, in terms of cost and risk reduction, must support that program's objectives. In a few of the nearer term satellite programs in which extensive program planning has been conducted, satellite sponsoring agencies have evaluated the benefits of specific satellite services to their program and concluded that they would be beneficial.

Because specific design characteristics are lacking in most projected satellite programs, an assessment of the benefit of various satellite services must be judged on the basis of engineering judgement and a generalized set of criteria. Figure 1-5 lists the

SERVICE FUNCTION	CRITERIA	RATIONALE
<b><u>DEPLOYMENT</u></b>	STS LAUNCHED	<ul style="list-style-type: none"> <li>● PLANNED, ASSUME ALL STS-ERA SATELLITES ARE ORBITER-DEPLOYED, DELIVERY TO DESIRED ORBIT IS ORBITER-DIRECT OR VIA PROPULSION STAGE</li> </ul>
<b><u>EXAMINATION</u></b>	STS LAUNCHED	<ul style="list-style-type: none"> <li>● BENEFICIAL IN EVENT OF MALFUNCTIONS PRIOR TO, OR AFTER, DEPLOYMENT</li> </ul>
	NEEDED FOR RETRIEVAL & SUPPORT OPERATIONS	<ul style="list-style-type: none"> <li>● PROVIDES INFORMATION TO RETRIEVE AND/OR SUPPORT SATELLITES AND/OR SPACE DEBRIS</li> </ul>
	POTENTIAL SCIENTIFIC BENEFITS	<ul style="list-style-type: none"> <li>● PLANNED OR ASSUMED REQUIREMENTS TO OBSERVE OR MEASURE ON-ORBIT PERFORMANCE OF EXPERIMENTAL SATELLITES (e.g., DEPLOYABLE ANTENNA)</li> </ul>
<b><u>RETRIEVAL</u></b>	APPARENT SATELLITE PROGRAM(S) BENEFITS	<ul style="list-style-type: none"> <li>● PLANNED, OR ASSUME AS POTENTIAL REQUIREMENT IF SATELLITE IS APPARENTLY HIGH IN DDT&amp;E COST</li> <li>● POTENTIAL SCIENTIFIC VALUE (e.g., EXTENSIVE EXPOSURE IN SEVERE SPACE ENVIRONMENTS)</li> </ul>
	COST EFFECTIVE	<ul style="list-style-type: none"> <li>● FOR SATELLITES BEYOND ORBITER REACH, ASSUME THAT RETRIEVAL VIA PROPULSION STAGE IS EFFECTIVE</li> </ul>
	SAFETY OF FLIGHT OPERATIONS	<ul style="list-style-type: none"> <li>● CAPTURE FOR DE-ORBIT MAY BE NECESSARY FOR POPULATION SAFETY OR DEBRIS REMOVAL</li> </ul>
<b><u>EARTH RETURN</u></b>		
- VIA ORBITER	APPARENT SATELLITE PROGRAM(S) BENEFITS	<ul style="list-style-type: none"> <li>● PLANNED, OR ASSUME AS POTENTIAL REQUIREMENT IF SATELLITE IS APPARENTLY HIGH IN DDT&amp;E COST</li> <li>● POTENTIAL SCIENTIFIC VALUE (e.g., EXTENSIVE EXPOSURE IN SEVERE SPACE ENVIRONMENTS)</li> </ul>
- VIA PROPULSION STAGE	SAFETY OF FLIGHT OPERATIONS	<ul style="list-style-type: none"> <li>● CONTROLLED DE-ORBIT ASSUMED NECESSARY FOR SATELLITES ESTIMATED FOR RE-ENTRY DURING 1983-93, FOR POPULATION SAFETY</li> <li>● DEBRIS REMOVAL MAY BE NECESSARY FOR SATELLITES IN POLAR ORBITS</li> </ul>
<b><u>SUPPORT</u></b>		
- CHECKOUT/REPAIR	STS LAUNCHED	<ul style="list-style-type: none"> <li>● PLANNED OR ASSUMED POTENTIAL REQUIREMENT TO MINIMIZE "INFANT MORTALITY" MALFUNCTIONS</li> </ul>
- MAINTENANCE	COST EFFECTIVE	<ul style="list-style-type: none"> <li>● APPLY TO SATELLITES WITH MISSION DURATIONS &gt; 12 TO 18 MONTHS <ul style="list-style-type: none"> <li>- LOW-ENERGY SATELLITES: <ul style="list-style-type: none"> <li>○ DIRECTLY REACHABLE BY ORBITER, ASSUME MAINTENANCE REDUCES SATELLITE PROGRAM COSTS</li> <li>○ PROPULSION STAGE BRINGS SATELLITE TO ORBITER, ASSUME RETRIEVAL/RETURN VIA PROPULSION STAGE IS EFFECTIVE</li> </ul> </li> <li>- HIGH ENERGY SATELLITES: - OUT OF SCOPE -</li> </ul> </li> </ul>
- RESUPPLY	COST EFFECTIVE	<ul style="list-style-type: none"> <li>● SAME AS FOR MAINTENANCE SERVICE FUNCTION</li> </ul>
- RECONFIGURE	POTENTIAL SATELLITE REQUIREMENT	<ul style="list-style-type: none"> <li>● ASSUME APPLICABLE FOR LARGE SATELLITE SENSOR PAYLOADS (SPACE TELESCOPE, SPACE PLATFORMS)</li> </ul>

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Fig. 1-5 Criteria for Identifying Service Needs

criteria and supporting rationale that have been developed to identify service functions deemed applicable to the projected satellite user community.

Orbiter deployment and on-orbit checkout, for example, will significantly reduce the "infant mortality" rate of new satellites. Studies have shown that satellite anomaly rate decreases with time and halves after the first 100 hours of on-orbit operation. Orbiter support of satellites in the early mission phase will contribute significantly to overall mission success for all satellite classes.

Reasoning and judgement must also be applied to the earth return service function when deciding upon a propulsion stage for de-orbit. In this case, the criterion is safety of flight operations since controlled de-orbit is assumed necessary for satellites re-entering during the 1983 - 1993 time frame. A further rationale is that debris removal may be necessary for satellites in polar orbits.

The STS ability to provide on-orbit maintenance also affords new avenues for satellite program cost reduction, particularly those with long observing time or program lifetime requirements. The lowest satellite program cost is a trade-off between increasing satellite reliability and the cost of Shuttle repair. Studies conducted by Grumman in the early 1970's\* have compared the cost to double a given satellite's lifetime through design (increasing redundancy to increase MTBF) to the cost of Shuttle servicing. These studies concluded that satellites with requirements for extended lifetimes will indeed benefit from servicing/maintenance.

#### 1.4.2 Services Identification

Engineering judgement has been used to identify potential service needs (applying the rationale discussed previously), and each SUM satellite/payload was judged in terms of beneficial services. The following additional ground rules were applied to identify applicable services for the candidate satellites:

- Satellite User Model Code Designation
  - ☐ (Service Approved) - Satellite/Payloads known to be designed for servicing (e.g., MMS)
  - ☐ (Yes) - Services assumed beneficial
- Sorties/Pallet-mounted payloads could benefit from services

-----  
\* (1) "Satellite Long-Life Assurance: The Impact of the Shuttle Era", E. Diamond, J. Fragola, Grumman Aerospace Corp., AIAA Paper 72-225, March 1972  
(2) Earth Observatory Satellite System Definition Study, NAS5-20520, Report No. 6, Space Shuttle Interfaces/Utilization, Grumman Aerospace Corporation, October 1974

- High energy satellites (Geosynchronous) could benefit from checkout/repair on initial launch
- All payloads carried by the Orbiter are assumed returnable to earth on initial launch.

When services were known to be needed, they were designated in the User Model as S (Service Approved); when engineering judgement deemed the service beneficial, they were designated as Y (Yes) in the User Model. The use of this coding designation is illustrated in Fig. 1-6, which shows a typical computer output listing for a segment of the Satellite User Model. The satellites are matrixed against the potential satellite service needs:

- Deployment
- Examination
- Retrieval
- Support - Checkout/Repair
- Support - Maintenance
- Support - Resupply
- Support - Reconfiguration
- Earth Return.

SATELLITE	CATE- GORY	DEPL	EXAM	RETVL	SUPPORT C/O RPR	SUPPORT MAINT	SUPPORT RESUPPLY	SUPPORT RECONFIG	EARTH RETN	CNTM SENS	FILE NO
ERRS-EARTH RAD BUDGET	A	S	Y	Y	Y	Y	Y	Y	S	YES	282AVN
RCA-F	A	S	Y	Y	Y				S	...	283AVN
ARABSAT-A	A	S	Y	Y	Y				S	...	234AVN
OSS-2	A		Y		Y	Y	Y	Y	S	...	285AVN
AT & T-1	A	S	Y	Y	Y				S	...	286AVN
AMPTE-ACT MAG, PART E	A	S	Y	Y	Y				S	...	287AVN
SYNCOM IV-2 LEASAT	A	S	Y	Y	Y				S	...	
ST-SPACE TELESCOPE	A	S	S	S	S	S	S	S			
LDEF	A	S	S	S	S						
PALAPA-8/2	A	S	Y								

S = SERVICE APPROVED  
Y = YES, ASSUMED SERVICE

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Fig. 1-6 Satellite Service Needs

The complete service needs assessment of all SUM candidate satellites is documented in Appendix B of this volume.

#### 1.4.3 Histograms of Service Needs

Histograms of service needs are plotted in bar chart form in Fig. 1-7 according to the satellite's year of launch. All satellites/payloads are categorized as approved, planned, candidate, or opportunity. The number of service events in each category are shown referenced to the year of launch because the candidate satellites listed in the User Model only reflect launch (or deployment) events.

#### 1.4.4 Summary of Service Needs

Figure 1-8 illustrates a summary of the potential service needs identified within the User Model during the 1983 - 1988 time frame. Engineering judgement has been used to identify service needs that could apply to the year of launch and to revisit situations. Revisit totals for 1983 - 1988 are referenced to satellites in their year of launch. In developing the Satellite and Services User Model (Refer to Section 2), we have reflected these service needs in a time-related fashion.

Note that an extensive number of servicing events are potentially applicable to satellites/payloads in the Approved/Planned category. When considering nominal and contingency situations, most top-level service functions could be applicable to initial launch. Additionally, all of the illustrated service functions could be applicable during revisits.

Of the more than 1000 service events identified on the chart, the percentage breakouts that are applicable to initial launch and revisits are as follows (according to year of launch):

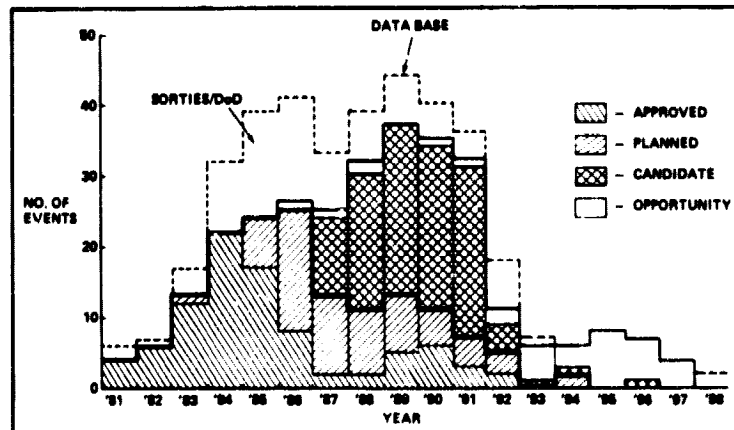
<u>INITIAL LAUNCH</u>		<u>REVISITS</u>	
● Deployment	- 14%	● Support	- 20%
● Examination	- 17%	- Maintenance	- (7%)
● Retrieval	- 14%	- Resupply	- (6.5%)
● Checkout/Repair	- 17%	- Reconfiguration	- (6.5%)
● Earth Return	- 18%		

ORIGINAL PAGE IS  
OF POOR QUALITY

• DEPLOYMENT

- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

MOST PAYLOADS DELIVERED TO ORBIT REQUIRE DEPLOYMENT. THOSE THAT DO NOT (IN THE CURRENT SERVICES MODEL), ARE SORTIE AND DoD MISSIONS. THE DoD MISSIONS THAT REQUIRE DEPLOYMENT ARE PROBABLY IN THE SAME RATIO AS THE OTHER MISSIONS IN THE MODEL, BUT INFORMATION ABOUT THEM IS NOT YET INCORPORATED.



Potential Deployment Needs

• DEPLOYMENT

• EXAMINATION

• RETRIEVAL

- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

DUE TO CONTINGENCY POSSIBILITIES, THE NUMBER OF SATELLITES THAT COULD BE RETRIEVED IS ALMOST THE SAME AS THE NUMBER DEPLOYED. SINCE SOME PAYLOADS ARE REMOVED FROM THE CARGO BAY BY THE RMS BUT NOT RELEASED, THEY HAVE NOT BEEN COUNTED IN THE RETRIEVAL SUMMARY.

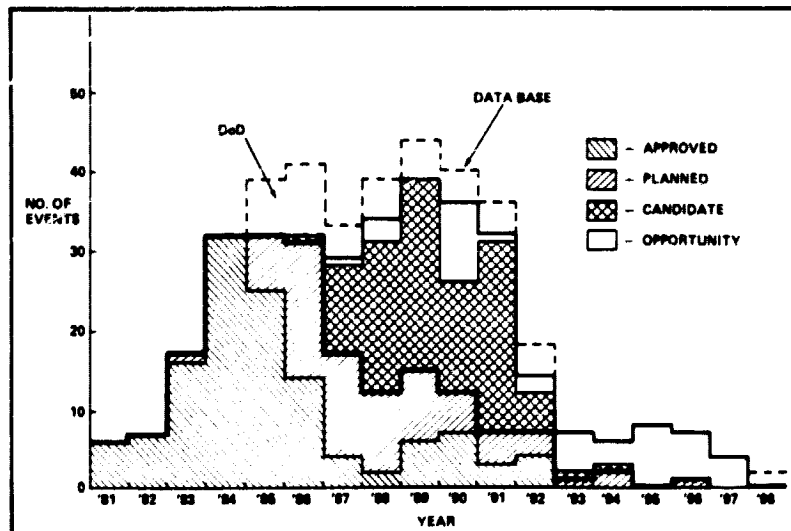
NO. OF  
EVENTS

• DEPLOYMENT

• EXAMINATION

- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

SORTIE PAYLOADS COULD UTILIZE THE EXAMINATION SERVICE, THEREFORE, MORE SATELLITES/PAYLOADS OF THE TOTAL MODEL APPLY AS COMPARED TO THE NUMBER IN THE PREVIOUS HISTOGRAM.



Potential Examination Needs

• DEPLOYMENT

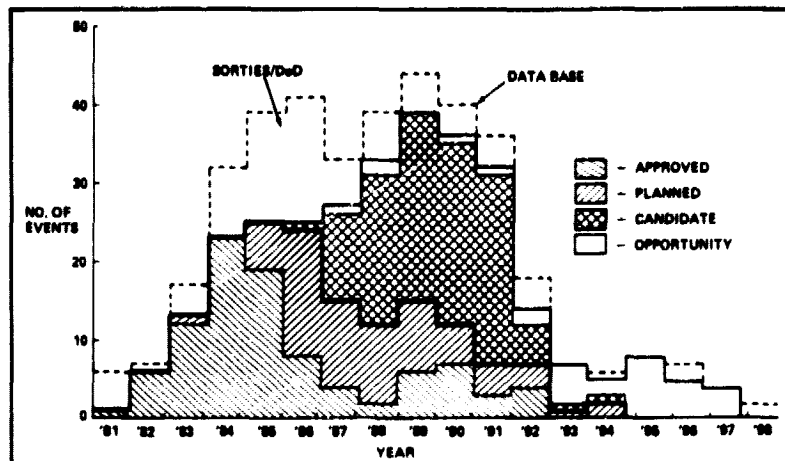
• EXAMINATION

• RETRIEVAL

- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

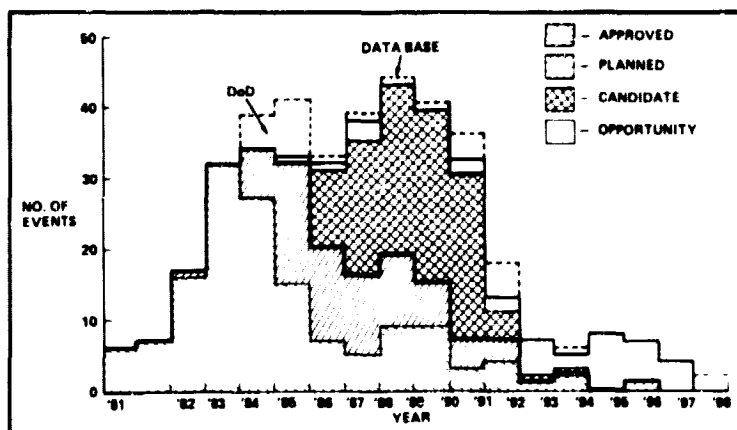
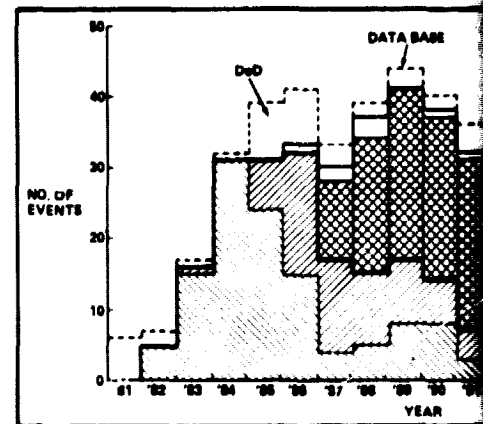
DUE TO ABORT/CONTINGENCY SITUATIONS, ALL PAYLOADS CARRIED IN THE ORBITER CARGO BAY HAVE EARTH RETURN CAPABILITY. POTENTIAL EARTH RETURN NEEDS WILL, THEREFORE, MATCH THE NUMBER OF PLANNED LAUNCHES.

NO. OF  
EVENTS



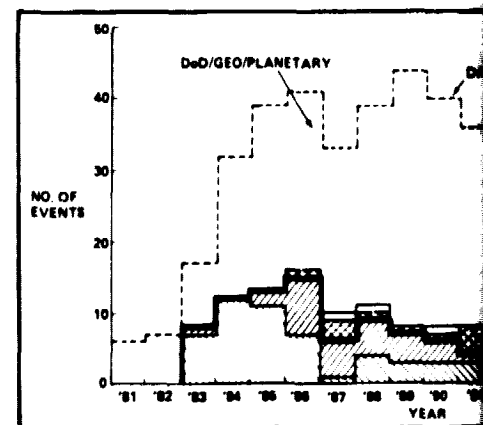
- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

MOST SATELLITES/PAYLOADS COULD BENEFIT FROM CHECKOUT/REPAIR AS SHOWN, EITHER IMMEDIATELY AFTER A MALFUNCTION IS APPARENT, OR AT A LATER TIME.

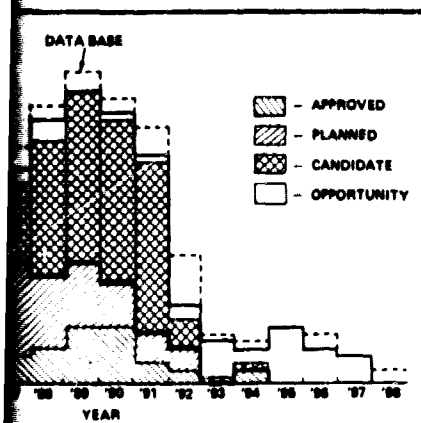


- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

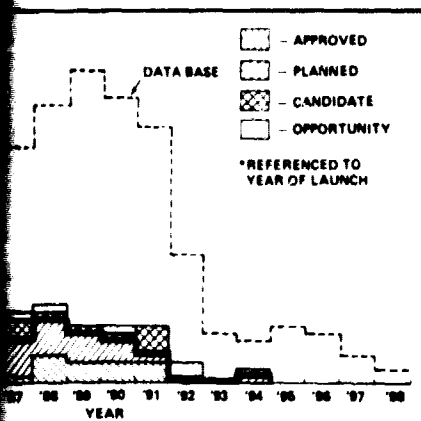
PLANNED MAINTENANCE REQUIRES THAT SATELLITES BE WITHIN RETRIEVAL RANGE OF THE ORBITER, OR ELSE BROUGHT TO IT FROM LEO. THIS EXCLUDES ALL GEO SATELLITES FROM THIS SUPPORT SERVICE. THIS SERVICE FUNCTION IS PRIMARILY APPLICABLE TO REVISIT MISSION EVENTS.







Checkout/Repair Needs

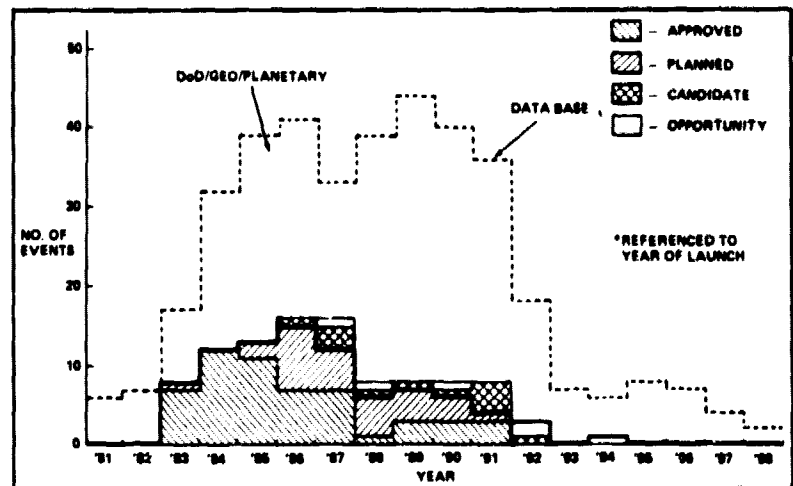


Maintenance Needs

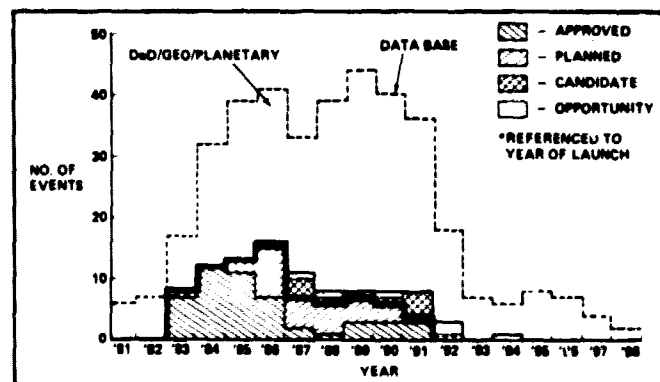
- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE

- RESUPPLY
- RECONFIGURATION

RESUPPLY IS NORMALLY A PLANNED EVENT AND REQUIRES THAT THE SATELLITE BE WITHIN RENDEZVOUS RANGE OF THE ORBITER, OR ELSE BROUGHT TO IT FROM LEO. THIS EXCLUDES ALL GEO SATELLITES FROM THIS SUPPORT SERVICE. THIS SERVICE FUNCTION IS ALSO PRIMARILY APPLICABLE TO REVISIT MISSION EVENTS.



Potential Resupply Needs



Potential Reconfiguration Needs

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

RECONFIGURATION IS NORMALLY A PLANNED EVENT AND REQUIRES THAT THE SATELLITE BE WITHIN RENDEZVOUS RANGE OF THE ORBITER, OR ELSE BROUGHT TO IT FROM LEO. THIS ELIMINATES ALL GEO SATELLITES FROM THIS SUPPORT SERVICE. AGAIN, THIS SERVICE FUNCTION IS PRIMARILY APPLICABLE TO REVISIT MISSION EVENTS.

Fig. 1-7 Histograms of Service Needs

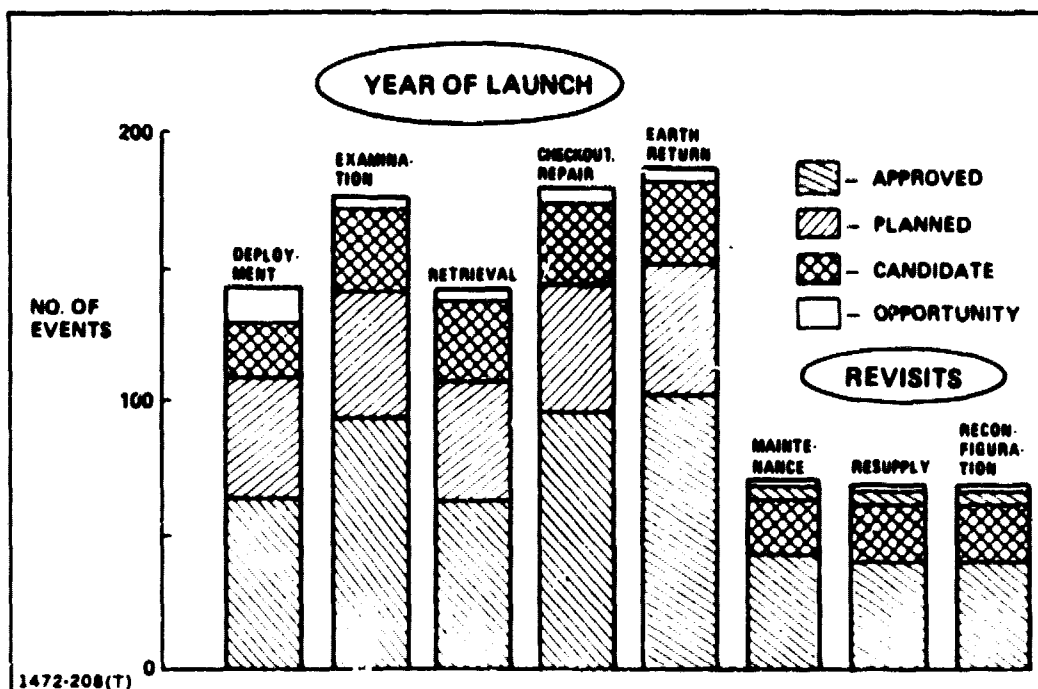


Fig. 1-8 Potential Service Needs Summary (1983 - 1988)

### 1.5 Manned, Remote, & Automated Involvement

Servicing options that require manned, remote, or automated involvement were identified for each top-level service function (see Fig. 1-9). These options, in conjunction with their related service function, formed the basis for assessing the extent of manned, remote, or automated involvement with all SUM satellites and payloads. The efforts reported herein were supported by Grumman's Independent Research and Development (IRAD) program.

#### 1.5.1 Groundrules for Identifying Servicing Options

Groundrules were formulated to ensure consistency of analysis and to enable a nominal approach to be applied to SUM satellites/payloads that lacked adequate design definition. The groundrules used to assess potentials for manned, remote, or automated involvement are:

- Satellite User Model Code Designation
  - **[M]** (Manned) - Direct Manned Involvement
  - **[R]** (Remote) - Remote with Man-in-the-Loop
  - **[A]** (Automatic) - Hands-Off Operation
- MMS-type satellites are RMS deployed
- SSUS satellites are automatically deployed

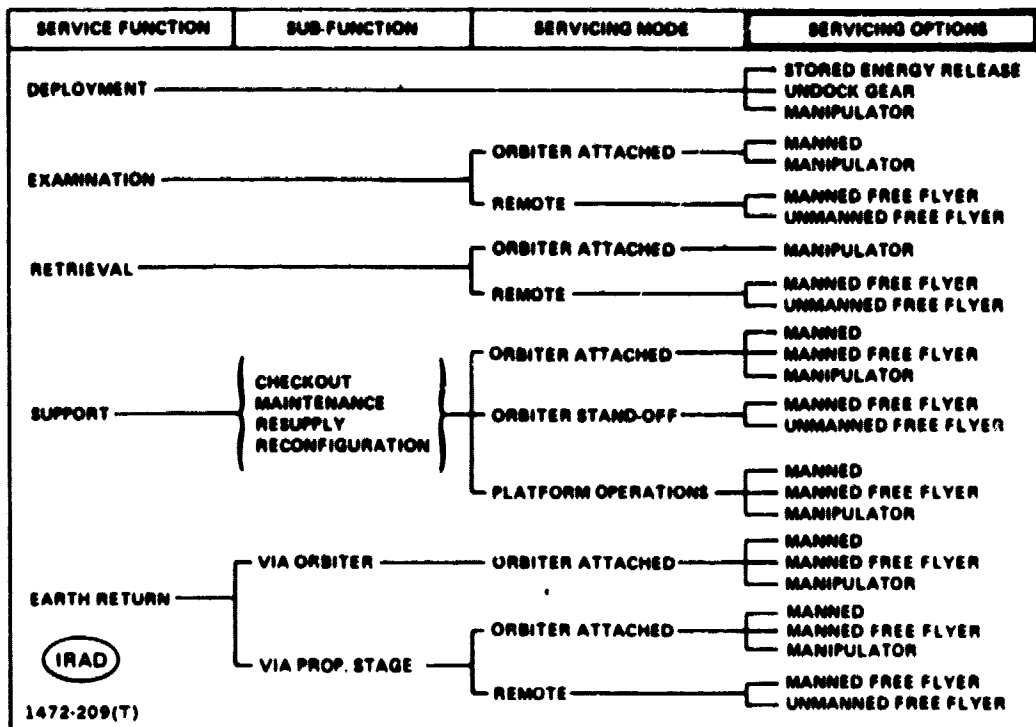


Fig. 1-9 Servicing Options Used to Assess Potential Manned, Remote, or Automated Involvement

- IUS satellites are RMS deployed or automatic
- Spacelab pallet examination is accomplished by EVA or RMS
- Contingency examination is available to all payloads
- Orbiter attached checkout is accomplished from the Aft Flight Deck
- Orbiter attached repair is accomplished by EVA, RMS, or MMU
- Maintenance, resupply, and reconfiguration capabilities are assumed for MMS-type satellites
- Earth return for most satellites is supported by RMS, with EVA backup
- All satellites within the Orbiter's capture capability could benefit from maintenance and resupply (excludes all high energy/planetary payloads).

### 1.5.2 Servicing Options Identification

Figure 1-10 illustrates the tabular listing developed to identify the potential for manned, remote, or automated involvement for each of the SUM candidate satellites. The categories of service options shown are consistent with the service options identified in Fig. 1-9. Note that when multiple service options are potentially applicable, the assess-

SATELLITE	SERVICE OPTIONS															
	REC EVA	FIG MFF	BA MMS	REC MFF	FIG UFF	OS	REC E/C	FIG MFF	PLT MMS	ER EVA	ORR MFF	ORR MMS	ER EVA	PRU MFF	ORR MMS	ER E/C
SATELLITE	SERVICE OPTIONS															
	MAI EVA	RT MFF	BA MMS	MAT MFF	RT UFF	OS	MAI E/C	RT MFF	PLT MMS	RES EVA	PLY MFF	BA MMS	RES MFF	PLY UFF	OS	RES E/C
SATELLITE	SERVICE OPTIONS															
	DEPL EGY	DEPL VON	DEPL MMS	ERAM EVA	ERAM MMS	ERAM UFF	ERAM UFF	RETV MMS	RETV MFF	RETV UFF	C/D EVA	RPR MFF	BA MMS	C/D MFF	RPR UFF	OS
EROS LANTH RAD BUDGET			R	M	R	M	R	R			M	M	R			
RCA F	A			M	R	M	R	R			M		R			
ARABSAT A	A			M	R	M	R	R			M		R			
OSB 2				M							M					
AT & T 1	A			M	R	M	R	R			M		R			
AMPTC ACT MAG PART E	A			M	R	M	R	R			M		R			
SYNCOM IV 2 LEASAT	A			M	R	M	R	R			M		R			
ST SPACE TELESCOPE			R	M	R	M	R	R			M	M	R			
LDLF			R	M	R	M		R			M					
PALPA 8/2	A			M	R	M										
IRAD																

1472-210(T)

Fig. 1-10 Manned, Remote, or Automated Involvement

ment retains these options. At this stage, our intent is not to identify "a solution", but rather to scope the extent of the issue and identify the likely service options to be expected.

The complete assessment of manned, remote, or automated involvement in satellite services, for all SUM satellites/payloads, is documented in Appendix B of this volume.

### 1.5.3 Service Functions Assessment - Manned, Remote, & Automated

An assessment of the potential extent of manned, remote (man-in-the-loop), and automated involvement in each SUM service function category is presented in Fig. 1-11. In each case, the potential "involvement events" are compared to the total of applicable satellites for that service function during 1983 to 1988.

### 1.5.4 Summary of Service Modes

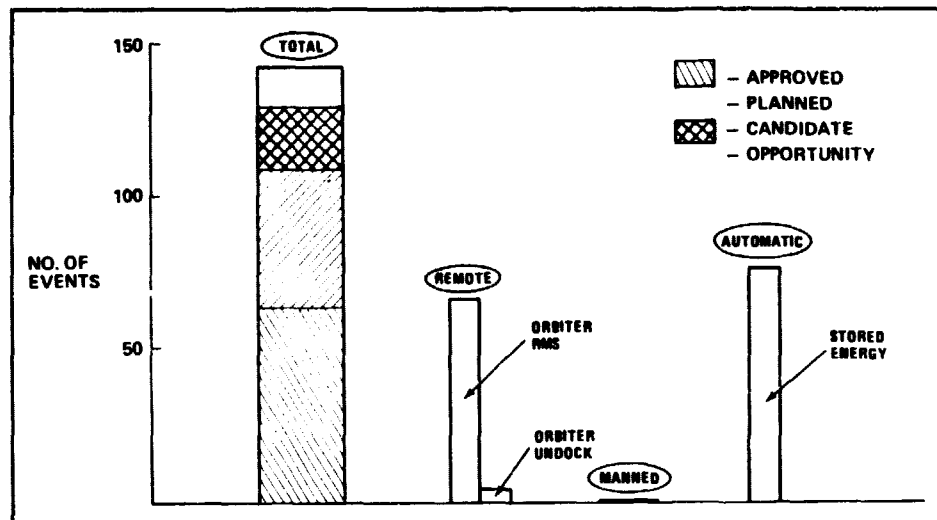
A summary of the most likely service modes, applying to SUM satellites/payloads in the 1983 - 1988 time frame, is shown in Fig. 1-12. Alternate servicing options were identified and served as the framework to identify the potential extent of manned, remote (man-in-the-loop), and automated involvement. Engineering judgement was then

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• DEPLOYMENT

- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

OUR ASSESSMENT INDICATES THAT THE NUMBER OF POTENTIAL REMOTE AND AUTOMATED DEPLOYMENTS IS APPROXIMATELY EQUAL IN THE CANDIDATE SERVICES MODEL. A LARGE PERCENTAGE OF THE DEPLOYED SATELLITES USE SSUS STAGES (AUTOMATIC) (E.G., GEO INSERTION OF COMMUNICATION SATELLITES).



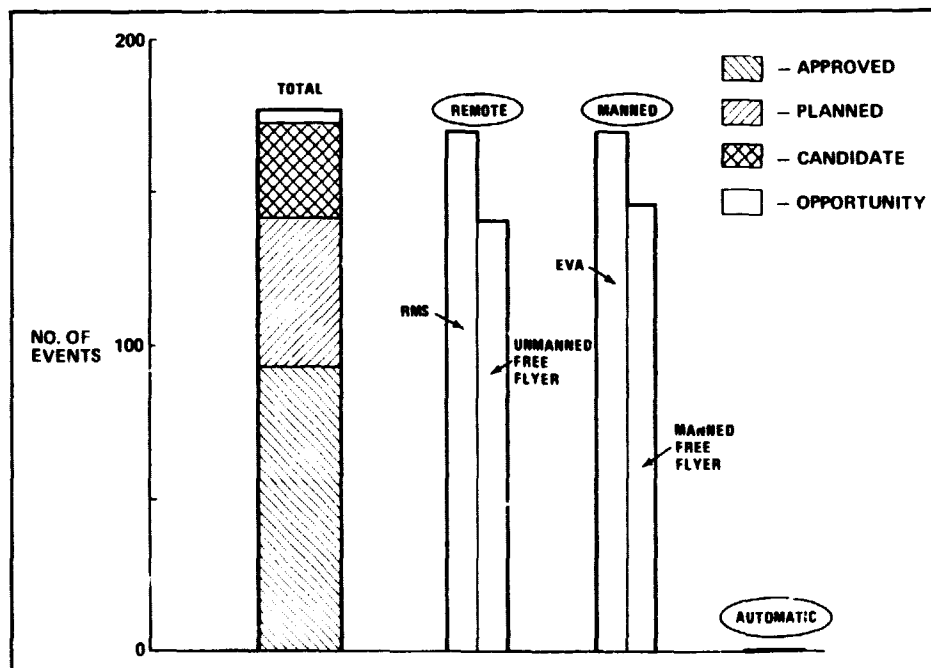
Deployment Options (1983-1988)

• DEPLOYMENT

• EXAMINATION

- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

SATELLITES CAN BE EXAMINED DIRECTLY WITH MANNED INVOLVEMENT OR REMOTELY, AS INDICATED.



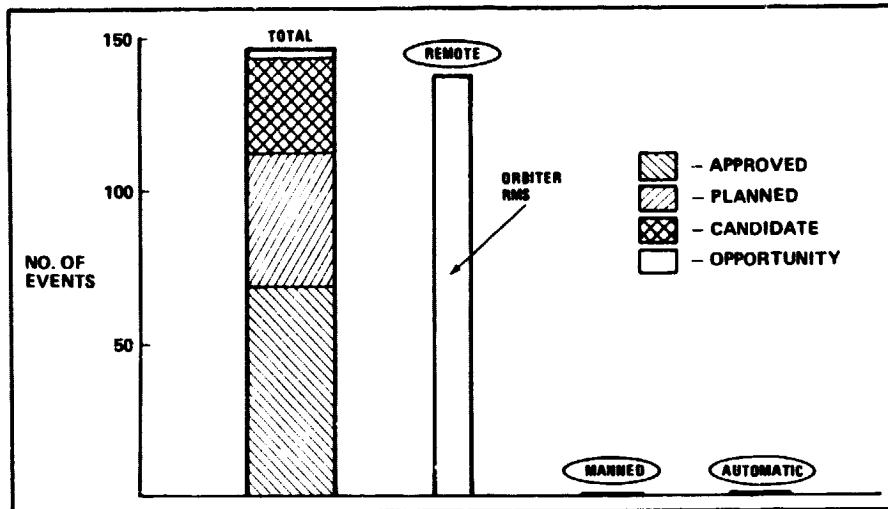
Examination Options (1983-1988)

IRAD

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OF POOR QUALITY

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

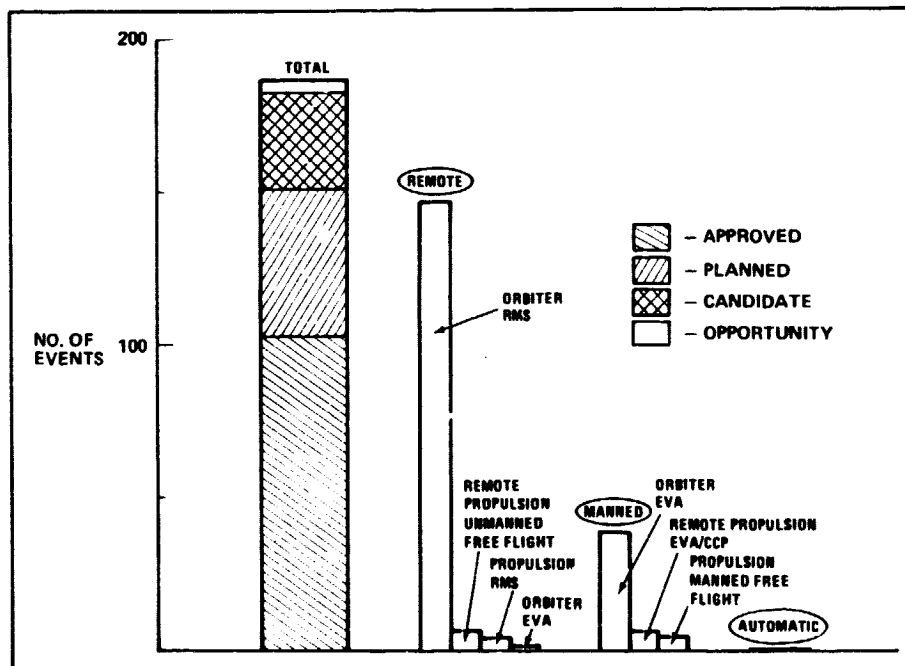
THE RMS PLAYS THE MAJOR  
ROLE IN RETRIEVING SATEL-  
LITES AND HUMAN INVOLVE-  
MENT IS REMOTE DURING THIS  
SERVICE.



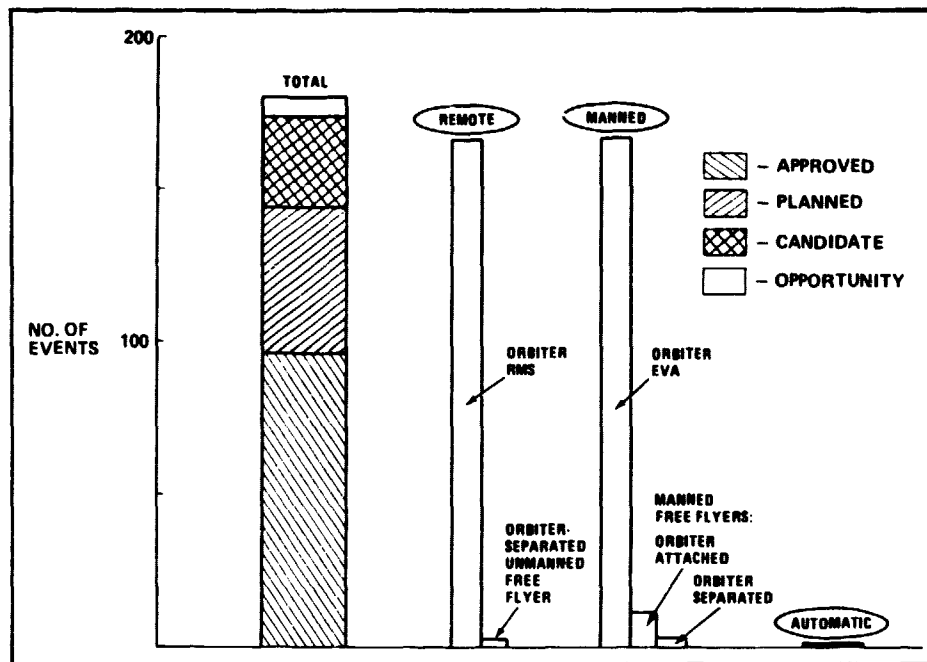
Retrieval Options (1983-1988)

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

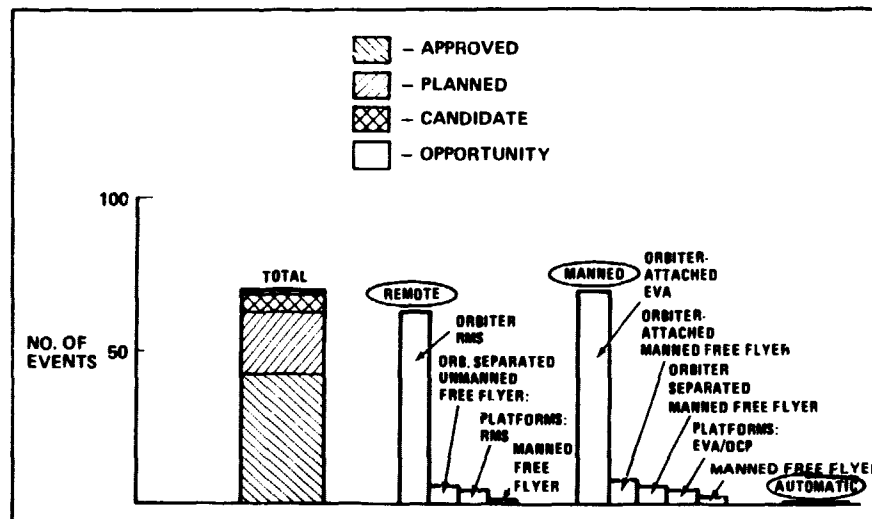
OPERATIONS INVOLVED WITH  
PREPARING A SATELLITE FOR  
EARTH RETURN (SUCH AS RE-  
MOVAL OF SOLAR ARRAYS OR  
ANTENNAS) COULD INVOLVE  
REMOTE PYROTECHNIC OPERA-  
TIONS AND, IN THE MAJORITY  
OF CASES, RMS-AIDED STOWAGE  
IN THE CARGO BAY.



Earth Return Options (1983-1988)



Checkout/Repair Options (1983-1988)



Maintenance Options (1983-1988)

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

HUMAN INVOLVEMENT IN CHECKOUT IS VIA IVA (FROM THE AFT FLIGHT DECK), AND REPAIR IS BY DIRECT EVA (EQUIPMENT CHANGEOUT) AND/OR USE OF THE RMS (REMOTE OPERATION) IN AN OPEN CHERRY PICKER SERVICE MODE.

- DEPLOYMENT
  - EXAMINATION
  - RETRIEVAL
  - EARTH RETURN
  - CHECKOUT/REPAIR
  - MAINTENANCE
  - RESUPPLY
  - RECONFIGURATION
- (RESUPPLY HEAVILY ON HANDS-ON REMOTE OPERATIONS ONLY MINIMIZED)

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

MAINTENANCE OPERATIONS RELY HEAVILY ON HUMAN INVOLVEMENT EITHER DIRECTLY VIA EVA OR WITH RMS (REMOTE) OPERATIONS. ONLY MINIMAL USAGE IS EXPECTED OF OTHER SERVICE MODES.

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

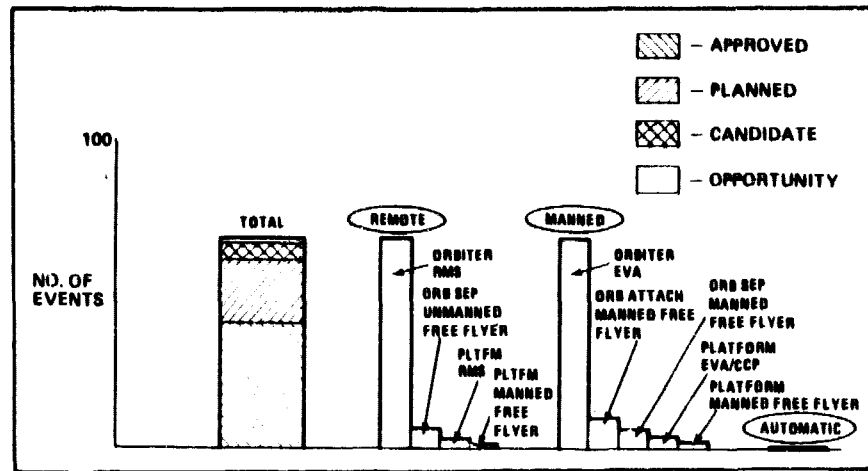
RECONFIGURATION OPERATIONS RELY HEAVILY ON HUMAN INVOLVEMENT; EITHER DIRECTLY HANDS-ON EVA OR WITH RMS REMOTE OPERATIONS. ONLY MINIMAL USAGE IS EXPECTED OF OTHER SERVICE MODES.

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE

**RESUPPLY**

- RECONFIGURATION

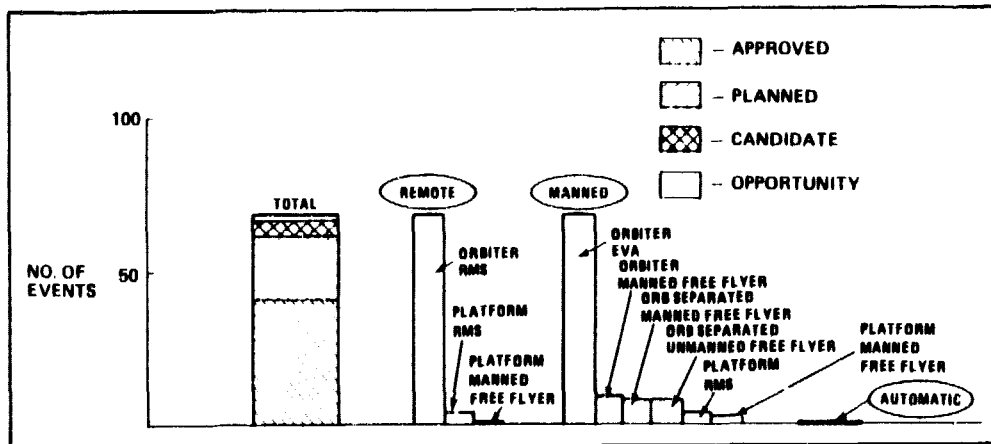
RESUPPLY OPERATIONS RELY HEAVILY ON HUMAN INVOLVEMENT; EITHER DIRECTLY HANDS-ON EVA, OR WITH RMS REMOTE OPERATIONS. AGAIN, ONLY MINIMAL USAGE IS EXPECTED OF OTHER MODES.



Resupply Options (1983-1988)

- DEPLOYMENT
- EXAMINATION
- RETRIEVAL
- EARTH RETURN
- CHECKOUT/REPAIR
- MAINTENANCE
- RESUPPLY
- RECONFIGURATION

RECONFIGURATION OPERATIONS RELY HEAVILY ON HUMAN INVOLVEMENT; EITHER DIRECTLY HANDS-ON EVA, OR WITH RMS REMOTE OPERATIONS. AGAIN, ONLY MINIMAL USAGE IS EXPECTED OF OTHER MODES.



Reconfiguration Options (1983-1988)

Fig. 1-11 Service Functions Assessment – Manned, Remote, or Automated Involvement



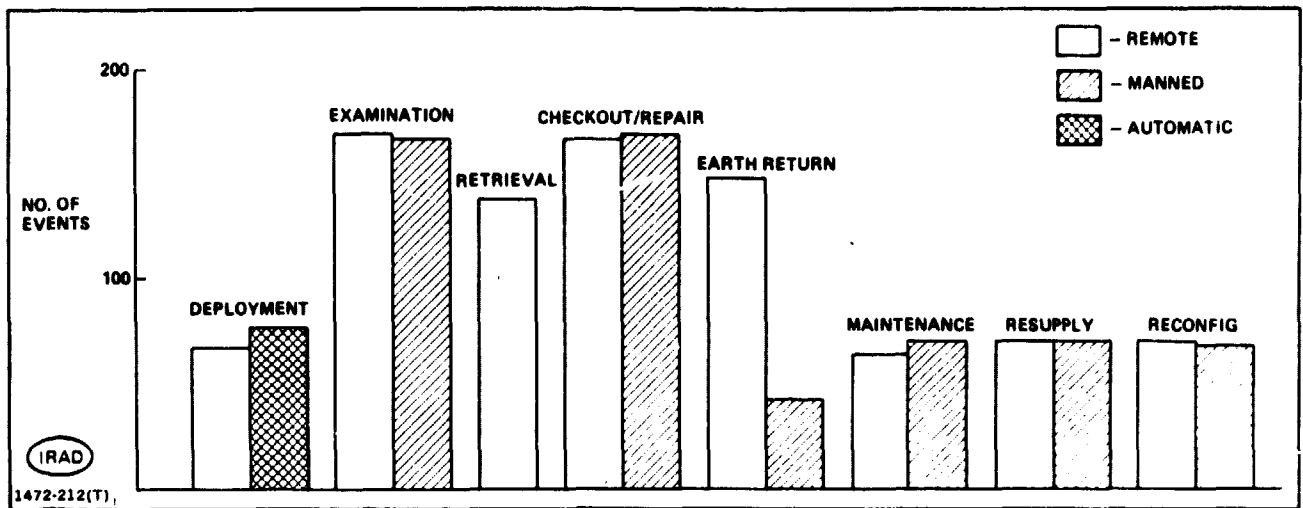


Fig. 1-12 Comparison of Most Likely Service Modes (1983-1988)

applied to establish potentially applicable service options. For example, in most cases, multiple options were applicable and were retained (the total of options, therefore, exceeds the number of satellites/payloads in the model). Our intent has been to scope the potential of this issue rather than to perform detailed evaluations that would be better applied to specific satellites.

The chart indicates, for example, that the most likely deployment modes are remote (man-in-the-loop e.g., RMS) and automatic, as expected. Examination and checkout/repair are almost equally distributed for remote and manned-direct; retrieval and earth return are major candidates for remote operations. The support functions of maintenance, resupply, and reconfiguration indicate almost an equal distribution of remote and manned-direct involvement.

Figure 1-12 also indicates the number of events that might be applicable for the various service functions as applied to SUM satellites/payloads. Of more than 1200 potential servicing modes considered, the breakout indicates:

- Manned-direct - 39%
- Remote (man-in-the-loop) - 55%
- Automatic - 6%

Clearly, the most likely situations will involve a human interface; either directly, or remote.

## 1.6 INACTIVE SATELLITES/DEBRIS

This subsection describes the investigations and assessments related to inactive satellites/debris to determine the merits or validity of including these objects within the scope of this study.

### 1.6.1 Projected Population of Inactive Satellites/Debris

The continued use of space by many nations has resulted in the placement of large numbers of spacecraft and associated debris in earth orbit. Many of these spacecraft remain in orbit years beyond their mission lifetime. Furthermore, many satellites are in orbits that cross the paths of other spacecraft (or inactive debris), and a finite probability of collision exists. Since satellite collision can produce fragments capable of damaging or fragmenting other satellites, an exponential increase results in the number of objects in low earth orbit (LEO).

Figure 1-13 shows a growth estimate for space objects and debris, as a function of time, based upon current growth trends. Results show that as many as 30,000 objects could be in LEO by 1995. The extent of a potential problem is identified, namely, a spacecraft measuring 50 meters in radius (e.g., a large space station) could have as much as a 50% probability of colliding during a 1000 day orbital lifetime.

One solution considered by this study is to investigate techniques for retrieval or de-orbit of inactive satellites and large pieces of debris. Debris that is larger than 3 m<sup>2</sup> is considered to be a candidate.

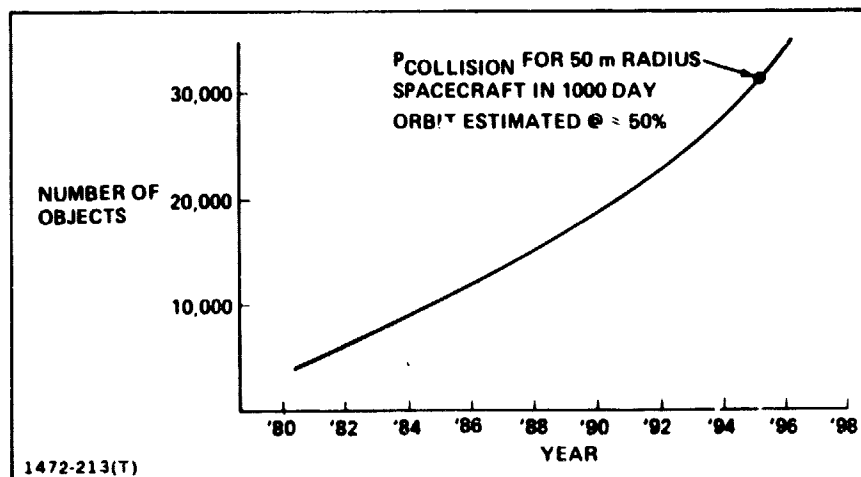


Fig. 1-13 Inactive Satellites/Debris – Potential Population in Orbit

### 1.6.2 Probability of Collision

Using the estimated orbital debris population shown in Fig. 1-13, the probabilities of collision for a spacecraft in orbit were computed. Figure 1-14 shows the probabilities of collision for a spherical satellite measuring 50 meters in radius and remaining in orbit for a period of three years. The data is shown for two altitudes, 800 km and 500 km, as a function of orbit inclination. The curves are based on an assumed orbit debris population of 10,000 objects which is estimated by 1985.

Collision probabilities are highly pronounced in the region of polar and sun-synchronous orbits. In fact, a collision probability of nearly 16% is exhibited at an inclination of 110 degrees for 800 km altitude orbits. One consolation is the fact that these probabilities pertain to very large area satellites (such as large space structures) and not to conventional satellites that are significantly smaller in projected area.

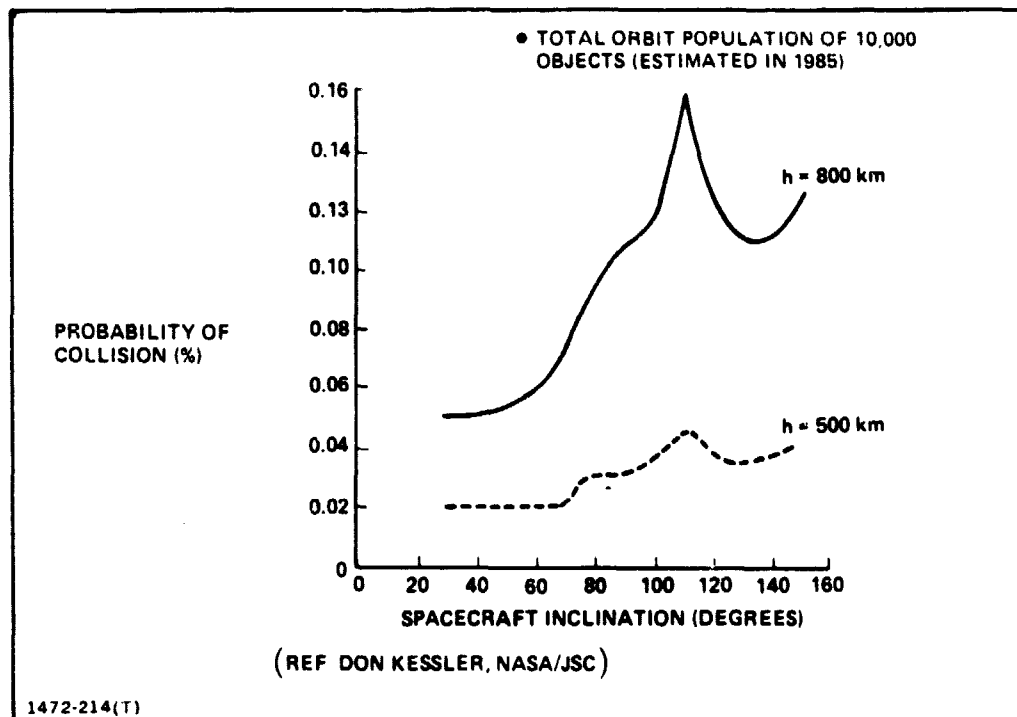


Fig. 1-14 Probability of Colliding With 50 Meter Radius Sphere in Orbit for 1000 Days

Figure 1-15 shows a replot of the probabilities of collision for more conventional satellites, those with projected areas of 30 square meters ( $m^2$ ). It is also based on an orbital debris population of 10,000 objects for satellite altitudes of 800 and 500 km. As noted, the probability of collision is about 100th of that for a 50 m radius sphere, peaking at a probability of less than 0.2% and an inclination of 110 degrees.

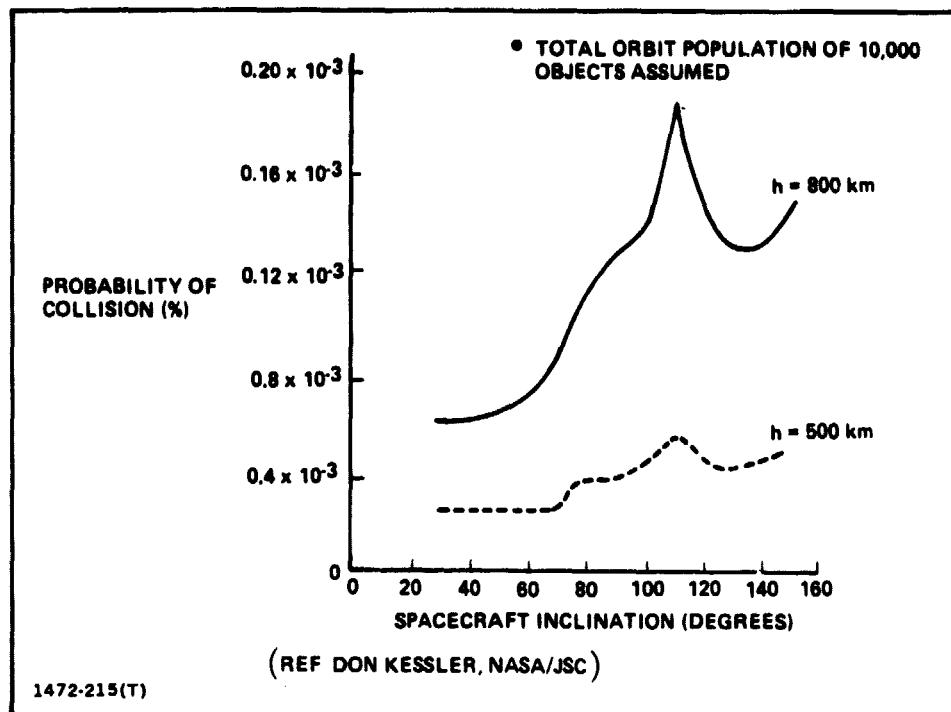


Fig. 1-15 Probability of Colliding With  $30 \text{ m}^2$  Satellite in Orbit for 1000 Days

Although the probabilities of collision for a conventional size spacecraft do not appear to pose a high risk situation in the mid-80s, an increasing trend is evident and should be dealt with in the future.

### 1.6.3 Debris Distribution by Size

As estimate of the distribution of objects in orbit with projected areas greater than  $3 \text{ m}^2$  is presented in Fig. 1-16. The chart was constructed using a 4% random sample of the NORAD Satellite Compilation (1 July 1980) of objects measuring  $2.7 \text{ m}^2$  or larger. Groupings were selected in categories of twice the cross sectional area.

Results indicate that the largest number of orbiting debris measure between 10 and  $20 \text{ m}^2$ . Figure 1-16 also shows, for the 10 to  $20 \text{ m}^2$  cross-sectional area grouping, the approximate percentage of these objects in the 500 to 1100 km altitude region. This is also somewhat representative of all groupings.

The results suggest that emphasis should be placed on the removal of objects in the 10 to  $20 \text{ m}^2$  range, since these pose the highest threat of collision with active spacecraft.

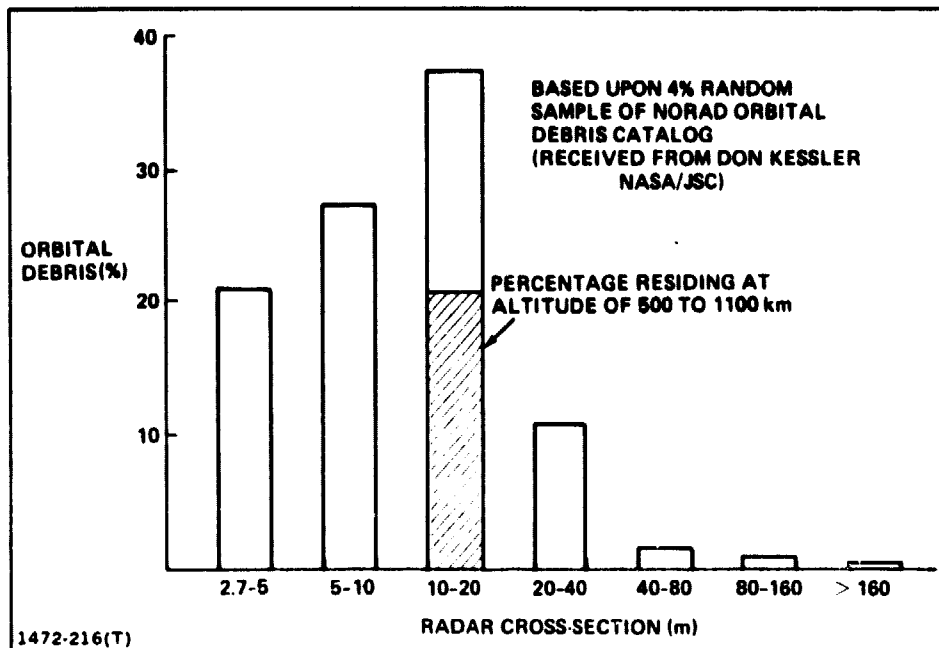


Fig. 1-16 Distribution of Orbital Debris by Radar Cross Sectional Area

#### 1.6.4 Conclusions & Recommendations

The following conclusions have been derived from the foregoing analysis:

- Current trends show a continued growth in the quantity of orbital debris. A principle cause for this growth is the collision of inactive satellites and spent launch vehicles with other orbiting fragments. This results in an exponential increase in the number of objects in low earth orbit
- Given the projected growth of orbital debris, the probability of collision for a conventional size satellite (placed in low earth orbit) does not appear critical (less than 0.2%) through the 1980s. It does, however, show cause for concern by the late 1990s
- The probability of collision for large spacecraft (hundreds of square meters in projected area) appears to be high, particularly in near polar LEO orbits, starting in the mid to late 1980's. If plans to orbit large satellites in the late 1980s or early 1990s mature (e.g., Space Operations Center), action should be taken to reduce the growth in orbital debris.

The following recommendations are offered:

- Future studies should address a logical program plan/approach for the retrieval and removal of inactive satellites and debris. In addition to satellite collision

probabilities, the removal of inactive satellites and debris might be further justified on the basis of removing potential re-entry hazards to populated areas, and the recovery of satellites exposed to the orbit environment over long durations could be returned for scientific observation

- Because orbital debris information (i.e., size, shape, and degree of stabilization) is lacking, this study has addressed retrieval of inactive satellites only. An acceptable candidate for use as a reference satellite is the Orbiting Astronomical Observatory (OAO). The OAO currently resides at the altitude of interest, has been on-orbit for more than 10 years, is of interest for scientific exposure observations, and is typical (size and radar cross section area) of objects with high collision probability.

## 2 - SATELLITE & SERVICES USER MODEL DEVELOPMENT

This section describes the development of the Satellite and Services User Model (S/SUM), the rationale/approach involved, and the overall results in terms of potential near-Orbiter service needs as a function of time. The efforts reported herein were supported by Grumman's Independent Research and Development (IRAD) program.

Throughout the initial phase of this study, major attention focused on the identification of potential service needs associated with candidate satellite programs of the future and the frequency of service events as a function of time. It became apparent, however, that a more meaningful way to group service functions/events was in terms of three mission events: Initial Launch, Revisits, and Earth Return. As shown in Fig. 2-1, Initial Launch nominally includes the service functions of checkout and deployment; Revisits include exam, retrieval, checkout, maintenance, resupply, reconfiguration, and deployment; and Earth Return involves exam, retrieval, and earth return. Each nominal mission event, therefore, signifies a given number of service functions. This simplification, in terms of mission events, was adopted in the formulation/development of the S/SUM.

• MAJOR MISSION EVENTS ARE BETTER MEASURES OF SERVICE NEEDS								
<u>MISSION EVENTS</u>			<u>NOMINAL SERVICE EVENTS</u>					
	DEPLOY	EXAM	RETRIEVAL	EARTH RETURN	CHECK-OUT	MAINT	RE-SUPPLY	RECONFIG
▲ INITIAL LAUNCH	•				•			
○ REVISITS	•	•	•		•	•	•	•
▼ EARTH RETURN		•	•	•				

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Fig. 2-1 Mission Events/Service Function Relationships

Development of the S/SUM is based upon the satellite listing identified in the Satellite User Model discussed in Section 1 and documented in Appendix A of this volume. The S/SUM extends the User Model to identify launches, revisits, and earth return service events. When the S/SUM model was completed, the original Satellite User Model was updated to reflect concurrence with S/SUM and is documented in Appendix D of this volume.

## 2.1 GROUND RULES & ASSUMPTIONS

Satellites and payloads in the S/SUM model have been grouped according to the satellite classes shown in Fig. 2-2. They include:

- Direct Delivery/Servicing - Those satellites capable of direct delivery to orbit and/or servicing by the Orbiter
- LEO/Propulsion - Those satellites whose LEO operational altitude is above the Orbiter's nominal delivery altitude
- GEO Satellites - Those satellites destined for GEO that are deployed in LEO by the Orbiter (does not include DoD satellites)
- Planetary/Others - Spacecraft destined for planetary missions that are deployed by the Orbiter. Undefinable satellites/payloads that might be carried as reflight opportunities in the STS manifest are also in this class
- Sorties/DoD - Sortie missions (e.g., Spacelab flights) and DoD Orbiter flights are grouped in this class.

### NOTE:

To retain the unclassified nature of this study, only publicly-known information relating to DoD flights or payloads is carried in Grumman's Satellite User Model.

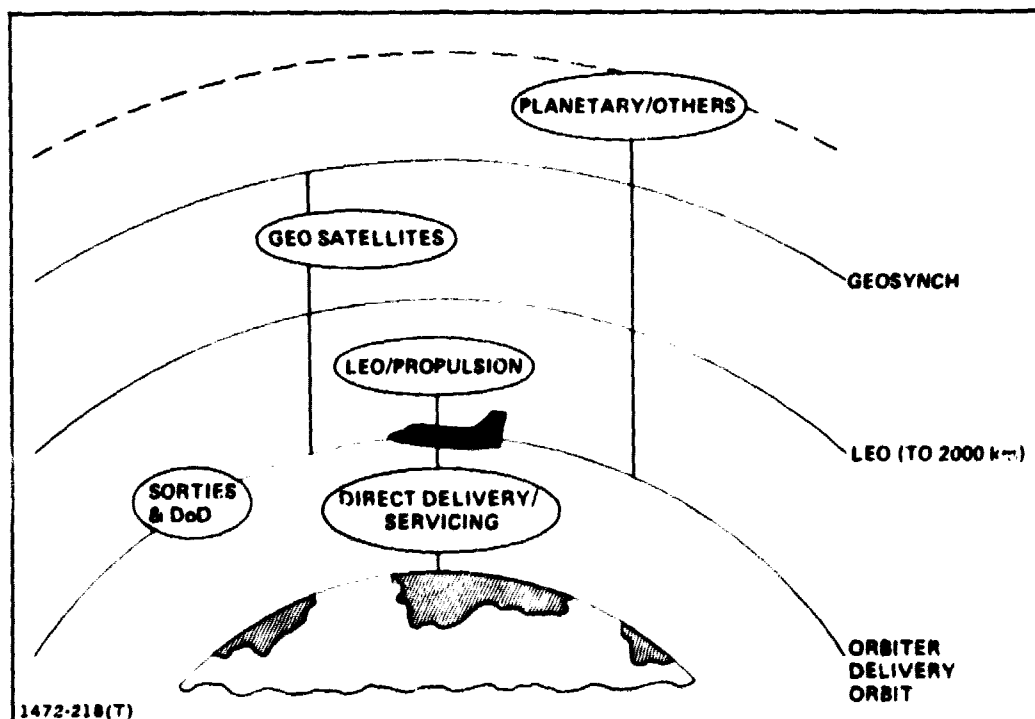


Fig. 2-2 S/SUM - Satellite Classes



The data base of S/SUM satellites and payloads, from 1981 to the year 2000, includes the following:

<u>SATELLITE CLASS</u>	<u>NO. OF SATELLITES/PAYLOADS</u>
Direct Delivery/Serviceing	29
LEO/Propulsion	40
GEO Satellites	54
Planetary/Others	37
Sorties/DoD	<u>51</u>
TOTAL	211

In structuring revisits and earth return events within the model, the following assumptions were made:

- Where data base sources reflect a satellite user's desire for a particular service event (e.g., launch, revisit, earth return), this has been reflected as a darkened symbol

	<u>Service Event Code</u>	<u>User Desire</u>
Launch	▲	▲
Revisit	○	●
Earth Return	▼	▼

- Satellites with planned operational lifetimes of more than 12-18 months and with masses greater than 500 kg are candidates for servicing revisits and retrieval for both Direct Delivery/Serviceing and LEO/Propulsion satellite classes
- Servicing revisits are on an annual basis for the Direct Delivery/Serviceing class and at two year intervals for the LEO/Propulsion class satellites
- Satellite users will avail themselves of servicing revisits and ground refurbishment, and will tend to extend their operational lifetime on orbit. This assumption has been applied to such satellites as
  - Large observatory type satellites such as Space Telescope, Advanced X-Ray Astronomy Facility (AXAF), Cosmic Ray Observatory (CRO)
  - Environment monitoring satellites such as Long Duration Exposure Facility (LDEF), Solar Cycles and Dynamics Mission (SCADM), Earth Radiation Budget Satellite (ERBS)

- Operational Earth Resources satellites such as Operational Land Observing System, Earth Survey, Private Earth Resources
- Unmanned Space Platforms such as Science and Applications Space Platform (SASP) and 25 kW Power Module
- Special mission satellites such as Gamma Ray Observatory (GRO), Upper Atmosphere Research Satellite (UARS), Ocean Research, Heavy Nuclei Explorer.

The model, therefore, reflects continued on-orbit activity for these satellite indicates both service revisits and earth return events.

- Operational DoD satellite systems will continue to be launched at regular intervals through the end of the century. This applies to such satellites as:
  - Global Positioning System (GPS)
  - Defense Satellite Communications System (DSCS)
  - Defense Meteorological Satellite Program (DMSP)
- Commercial communication satellite launches have been selectively extended (beyond the information in our data base) to reflect anticipated increases in satellite-based communications traffic
- Experimental Sortie activities will be maintained at annual or biannual rates; examples of these are:
  - Spacelab(s)
  - Space Test Program (DoD).

To provide the opportunity for near-Orbiter servicing to the satellite user whose LEO operational orbit altitude is above the Orbiter's nominal delivery orbit, two basic delivery/return options could apply. The servicing scenario options are illustrated in Fig. 2-3. A unique/integral propulsion stage could be provided by the satellite user with the capability to deliver the satellite to its operational altitude and return to the Orbiter for servicing and refueling at appropriate intervals (planned or unscheduled). An alternative would be to provide the satellite user with a Versatile Service Stage (VSS) that would deliver the satellite to its orbit and then return to the Orbiter for reuse. The VSS could also be used to return the satellite to the Orbiter for servicing or earth return. Either one of these propulsion system options are applicable to the LEO/Propulsion satellite class, as depicted in the S/SUM.

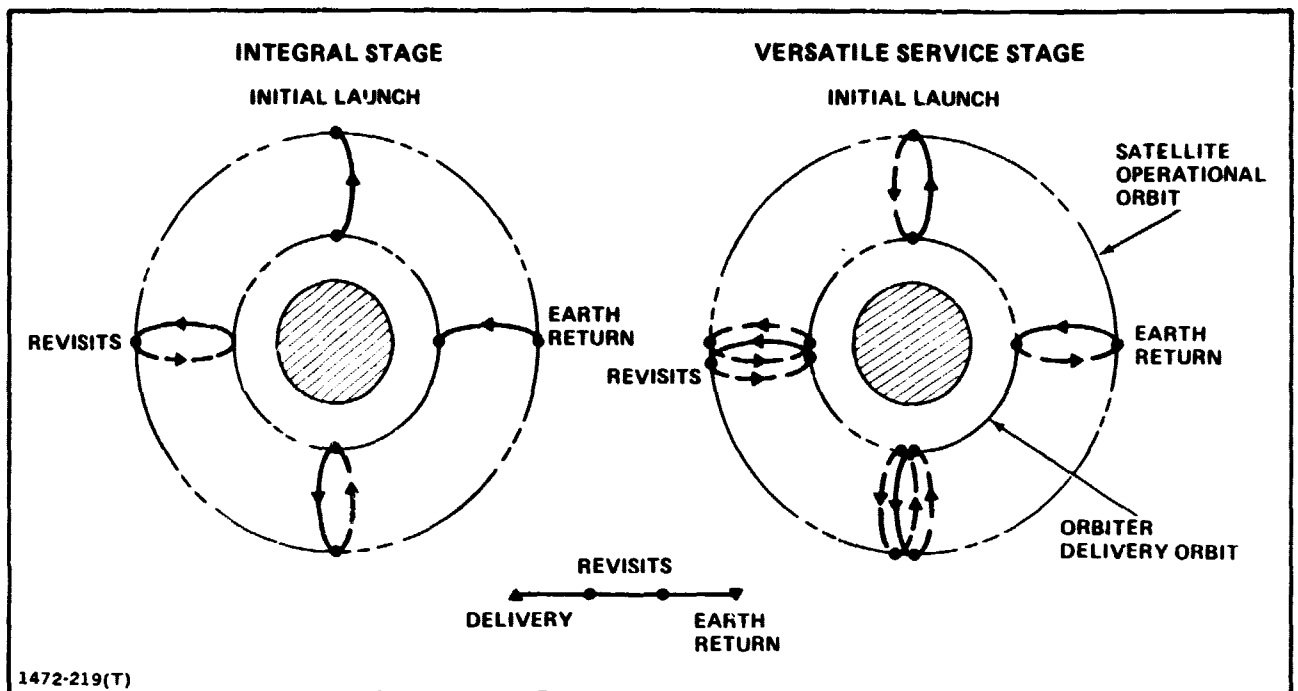


Fig. 2-3 LEO/Propulsion Satellite Class – Options for Servicing at Orbiter

## 2.2 SATELLITE & SERVICES USER MODEL (S/SUM)

The S/SUM is presented in Fig. 2-4 and grouped according to the following satellite classes:

- Satellites with Direct Delivery/Servicing by the Orbiter
- Satellites with LEO Propulsion
- GEO Satellites
- Planetary/Other
- Sortie Missions
- DoD Missions.

Reference sources shown in the model are coded as follows:

<u>Code</u>	<u>Source Reference</u>
5-YR	NASA Program Plan, Fiscal Years 1981 through 1985
AVN	Aviation Week
DoD	DoD STS Utilization Plan, July 1979
FAM	NASA Flight Assignment Manifest, JSC 13000-3, June 1980

<b>GAC</b>	<b>Grumman Information</b>
<b>GSF</b>	<b>Goddard Space Flight Center, Preliminary Project Descriptions, July 1980</b>
<b>IAF</b>	<b>International Astronautics Federation, Preprint 81-125, September 1981</b>
<b>LEP</b>	<b>Low Energy Payload Model, Battelle, September 1979</b>
<b>MDC</b>	<b>Mission Data Catalogue, Spacecraft Deployment Systems, LA-S-801, Martin Marietta, October 1979</b>
<b>MML</b>	<b>Multi-Mission Spacecraft Listing, Goddard Space Flight Center, July 1980</b>
<b>NAS</b>	<b>NASA STS Mission Model, JSC-13829, Ref. 1, October 1977</b>

Satellite codes correspond to designations of the NASA OAST Space Systems Technology Model, May 1980. Code explanations are:

<b>A</b>	<b>Astrophysics</b>
<b>C</b>	<b>Communications</b>
<b>E</b>	<b>Global Environment</b>
<b>EI</b>	<b>Global Environment Instruments</b>
<b>L</b>	<b>Life Sciences</b>
<b>OI</b>	<b>OAST Instrument Systems</b>
<b>P</b>	<b>Planetary</b>
<b>R</b>	<b>Resource Observation</b>
<b>S</b>	<b>Solar Terrestrial</b>
<b>T</b>	<b>Space Transportation</b>
<b>U</b>	<b>Utilization of Space Environment</b>
<b>UI</b>	<b>Utilization of Space Environment Instruments</b>

Each of the satellites listed in the model are categorized as follows:

- |            |                   |  |
|------------|-------------------|--|
| <b>[A]</b> | <b>(Approved)</b> | <b>- Missions authorized for implementation</b>                                |
| <b>[P]</b> | <b>(Planned)</b>  | <b>- Missions designated as possible new starts within the next five years</b> |

## LEGEND

△ LAUNCH EVENT

○ SERVICE EVENT

▽ RETURN EVENT

SHADED : USER IDENTIFIED

OPEN : ASSUMED

SATELLITE

WITH DIRECT DELIVERY/SERV

SATELLITE	REF	SPONSOR	CAT.	MASS(KG)	OPERATIONAL	
					ORBIT(KM)	INC (°)
SPAS-01 STS PALLET SAT.	(IAF)	MBB	A	1800	296	28
SPACE TELESCOPE	(A-3)	OSS	A	11000	593	28
LDEF	(01-10)	OAST	A	4500	509	28
GRAVSAT	(R-4 GSF)	OSTA	P	1600	160	90
GRO-GAMMA RAY OBSERV	(A-7)	OSS	P	11000	400	28
SASP-SCI & APP SP PLAT	(U-7 & L-2)	OSTA	P	40000	296	28
25KW PWR MOD	(U-8)	OST	P	14000	435	28
MAG FIELD SURV B	(R-7)	OSS	P	800	300	90
LG STRUCT CONSTR	(U-5)	OST	P		296	28
MATLS EXPERIMENT CARRIER	(U-9 & 10)	OSTS	P	5000	296	28
LOW ALTITUDE STUDIES OF ISONOSPHERIC IRREGULARITIES (NRL)		NRL, OSS	P	1400	300±90	28
						56
SUBSAT FACILITY	(S-9)	OST	P	500	296	28
AXAF-ADV X-RAY ASTRO	(A-9)	OSS	P	10000	450	28
CRO-COSMIC RAY OBSER	(A-13)	OSS	C	18000	400	50
GRAVITY PROBE B	(A-8)	OSS	P	1270	520	90
POLAIRE	(LEP)	CANADA	P	440	300	90
COASTAL SAT.	(NAS)	OSTA	P	4173	296	10
SOC-SP OPS CTR	(5 YR)	OST	P		300	28
OCEAN RESEARCH SAR	(E-11)	OSS	C		300	28
HVY NUCLEI EXPL	(GSF)	OSS	C	4000	400	50
LG SOLAR OBSERV	(LEP)	OSS	C	9800	350	28
SOLAR TERR OBS	(S-12)	OSTA	C	1000	400	50
ADVANCED RELATIVITY	(LEP)	OSS	C	910	520	90
SPS TEST ARTICLE	(MDC, U-13)	OST	C	136000	300/GEO	28
AMBIENT DEPLOY IR TELE	(A-17)	OSS	C	16000	500	28
IR INTERFEROMETER	(A-18)	OSS	O	22500	400	28
AUTO PLANET STA	(P-14)	OSS	O	25000	400	28
LARGE POWER MODULE	(U-11)	OSTS	C	29230	296	0-
LG OPT UV TELESCOPE	(A-21)	OSS	O	22800	450	28

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# SATELLITES

DELIVERY/SERVICING BY ORBITER

△<sup>x</sup> ← NO. OF LAUNCHES  
STS-X ← FLT MANIFEST NO

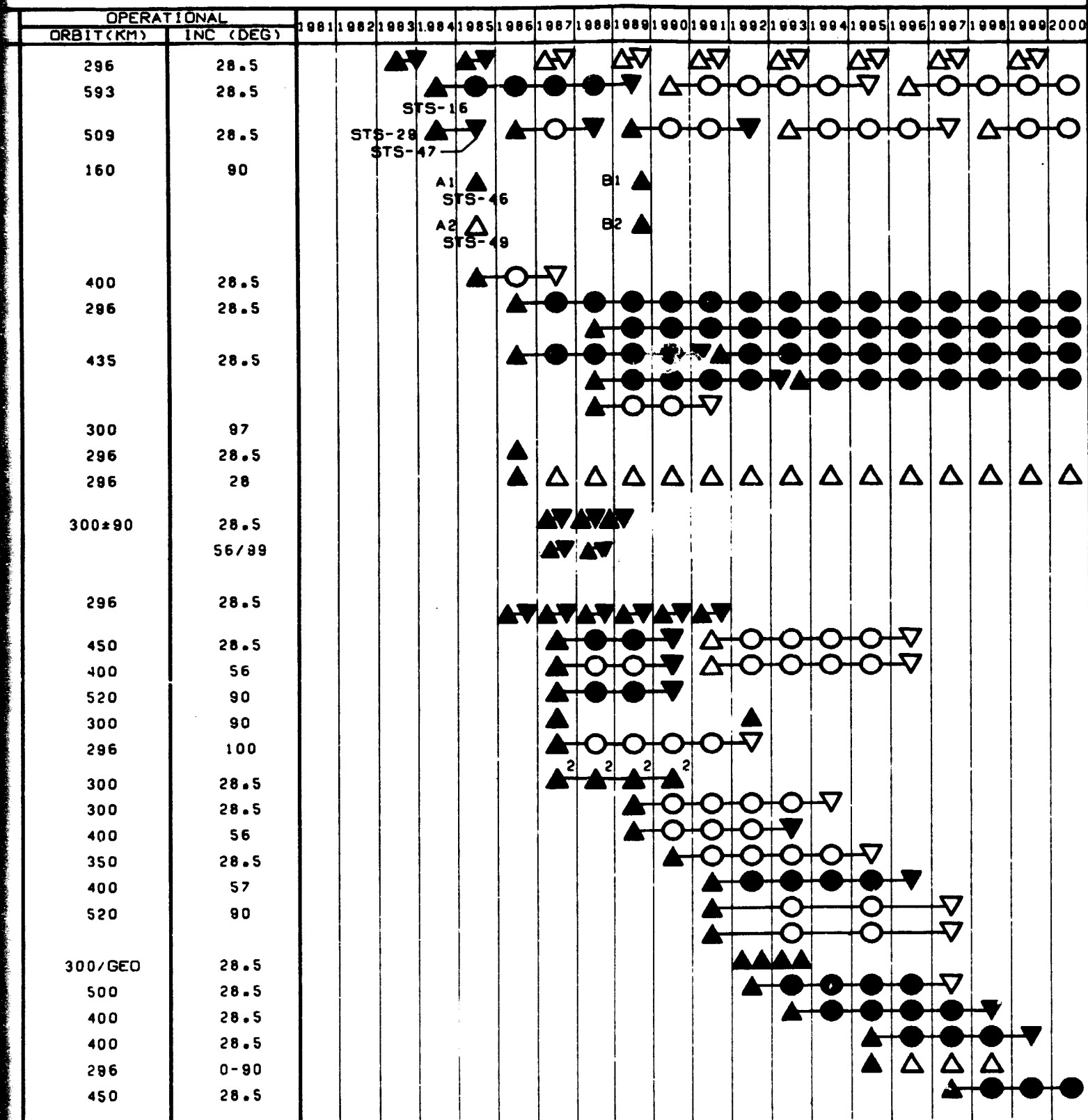


Fig. 2-4 Satellite and Services User Model (S/SUM)  
(Sheet 1 of 8)

LEGEND

- ▲ LAUNCH EVENT  
 ○ SERVICE EVENT  
 ▼ RETURN EVENT
- SHADED : USER IDENTIFIED  
 OPEN : ASSUMED

SATELLITES WITH LE

SATELLITE	REF	SPONSOR	CAT.	MASS (KG)	OPERATION	
					ORBIT/KM	I
LANDSAT D	(R-2)	NOAA	A	1597	705	
CHEM REL MODULE	(S-5)	OSS	A	2700	1200	
ERBS - EARTH RAD BUDGET SAT.	(E-4)	OSTA	A	1134	600	
SOLAR MAX - SMM	(S-1)	OSS	P	2455	514	
LANDSAT D''	(5 YR)	NOAA	P	1597	705	
LANDSAT D'''	(5 YR)	NOAA	P	1597	705	
NOAA	(E-5)	NOAA	A	4173	830	
			P	4173	830	
COBE - COSMIC BKGND EXPL	(GSF)	OSS	A	1421	900	
EUVE-EXTREME UV EXPLORER	(A-5,GSF)	OSS	A	400	550	
REGION H2O QUAL MON	(LEP)	OSTA	P	1000	700	
ORBITER CAMERA FREE FLYER	(MML)	OSS	C	1400	300++	
UARS-UPPER ATMOS RES	(E-7)	OSTA	P	3700	500	
NOSS-NAT OCEAN SAT.	(E-6)	OSTA	A	4500	787	
MAGSAT B	(R-1)	OSTA	P	272	550	
HI ENERGY EXPL	(NAS)	OSS	P	2268	463	
ASTROPHYSICS EXPL	(GSF)	OSS	C	-	525	
X-RAY TIME EXPL	(A-10,GSF)	OSS	P	1000	400	
ICEX-ICE & CLIN EXP	(5 YR)	OSTA	P	5000	700	
OP LAND OBSER SYS	(LEP,R-5)	OSTA	P	1700	700	

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FOIA b 7 - D

SPACECRAFT IDENTIFICATION → G Δ

SP203F

STS-X ← FLT MANIFEST NO.  
4W ← 4TH WTR LNCH

# SATellites WITH LEO PROPULSION

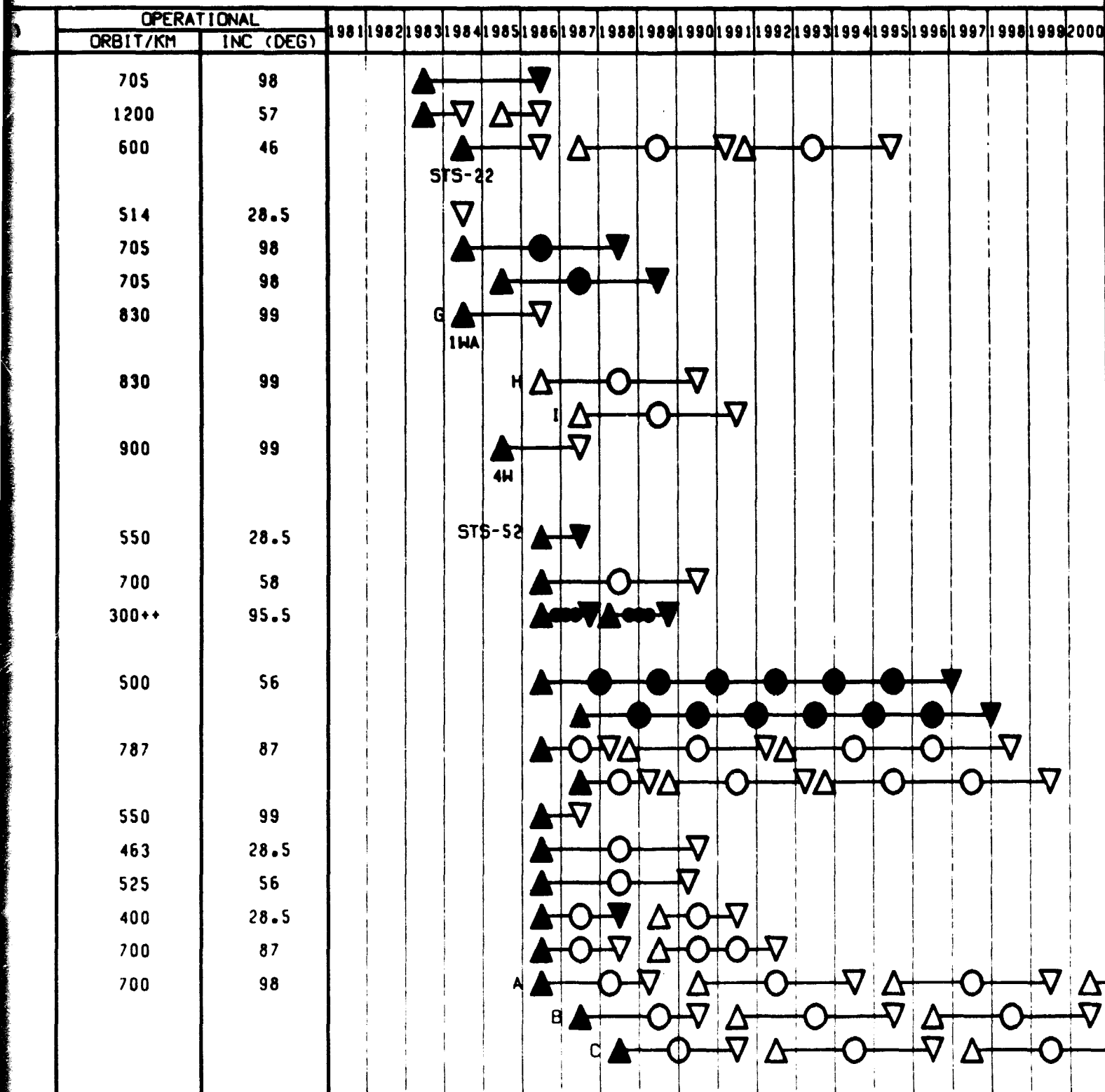


Fig. 2-4 Satellite and Services User Model (S/SUM) (Sheet 2 of 8)



LEGEND

- △ LAUNCH EVENT  
○ SERVICE EVENT  
▽ RETURN EVENT

SHADED : USER IDENTIFIED  
OPEN : ASSUMED

SATELLITES WITH LEO

SATELLITE	REF	SPONSOR	CAT.	MASS(KG)	OPERATIONAL	
					ORBIT/KM	IN
TOPEX-TOPOG EXP OCEAN CIRCULATION	(E-9)	OSTA	P	1000	700	
SOIL MOISTURE	(R-8)	OSTA	D	408	465	
ALL WEATHER MICROWAVE	(LEP)	CANADA	P	2000	790	
SCADM-SOLAR CYCLES & DYNAMICS MISSAS-13)		OSS	C	2600	575	
EARTH SURVEY	(LEP)	OSTA	P	772	910	
ADV GEOLOGY SAT.	(LEP)	OSTA	C	2000	700	
GLOBAL REGIONAL ATMOS MONITOR	(LEP)	OSTA	D	—	700	
LAMAR-LG AREA MOD ARRAY	(A-14,GSF)	OSS	C	5200	400	
PRIV EARTH RES	(LEP)	US INDUS	P	1700	700	
ATMAS-ADV THERM MAP	(R-6)	OSTA	P	1450	700	
VLBI-V LG BASE INT	(A-15)	OSS	P	—	1000	
GAMMA-RAY TRANSIENT EXPL	(GSF)	OSS	C	3000	450	
ENVIRON MONITOR	(LEP)	OSTA	C	1000	700	
OP METEOROLOGY	(E-10)	OSTA	P	4500	800	
ASTRONOMY	(MDC)	OSS	C	950	5000	
UV PHOTOMET/POLARIMET EXPL	(GSF)	OSS	C	545	400	
X-RAY OBSERVATORY	(GSF)	OSS	C	3550	400	
SOFT X-RAY SURVEY	(GSF)	OSS	C	1600	400	
MOLECULAR LINE SURVEY	(GSF)	OSS	C	1000	600	
X-RAY SPECTROSCOPY	(GSF)	OSS	C	1500	400	
SUBMILLIMETER TELESCOPE	(A-16)	OSS	C	1000	1000	

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# SATELLITES WITH LEO PROPULSION

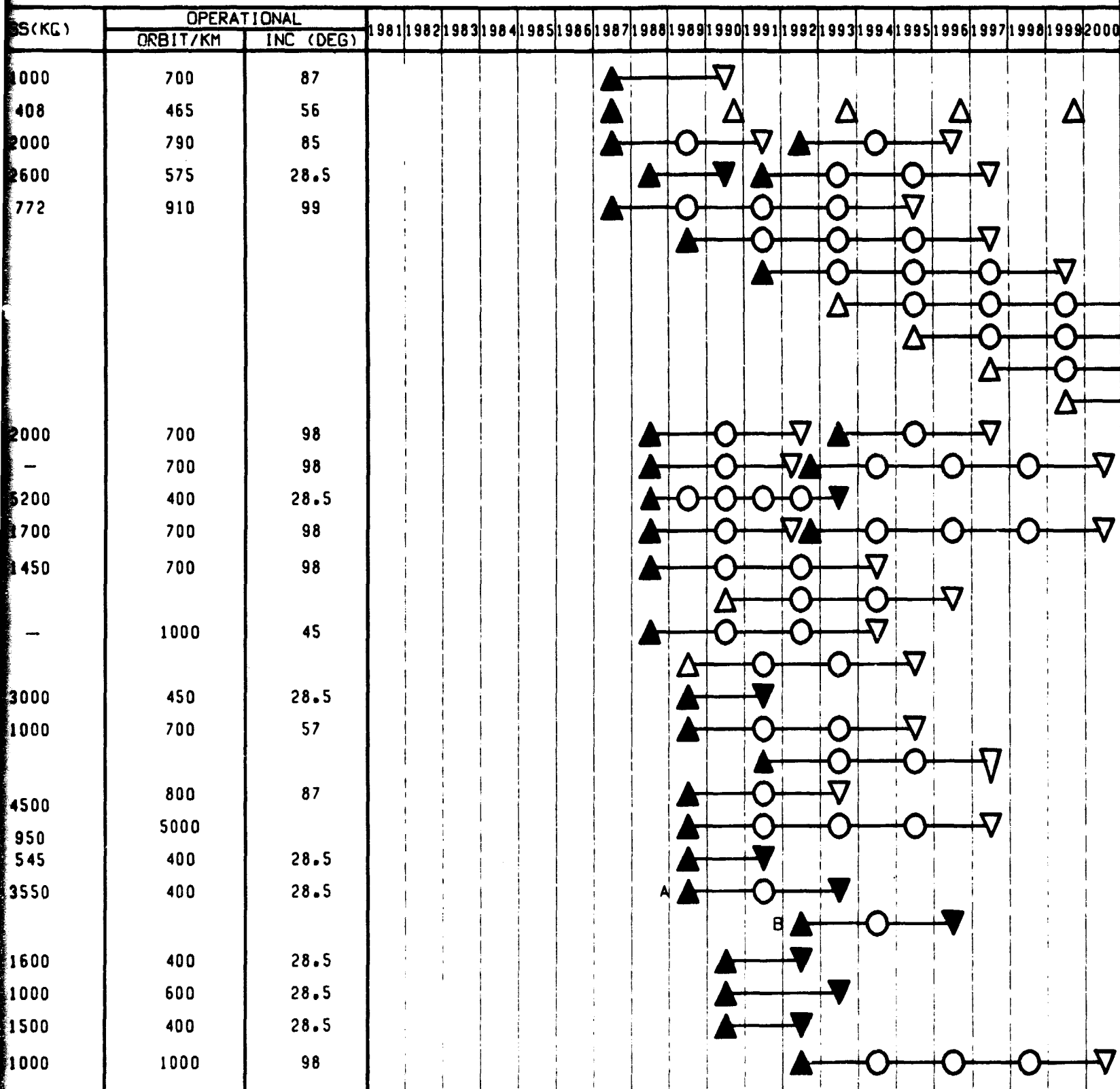


Fig. 2-4 Satellite and Services User Model (S/SUM)  
(Sheet 3 of 8)

## LEGEND

▲ LAUNCH EVENT  
 ○ SERVICE EVENT  
 ▼ RETURN EVENT

SHADED : USER IDENTIFIED  
 OPEN : ASSUMED

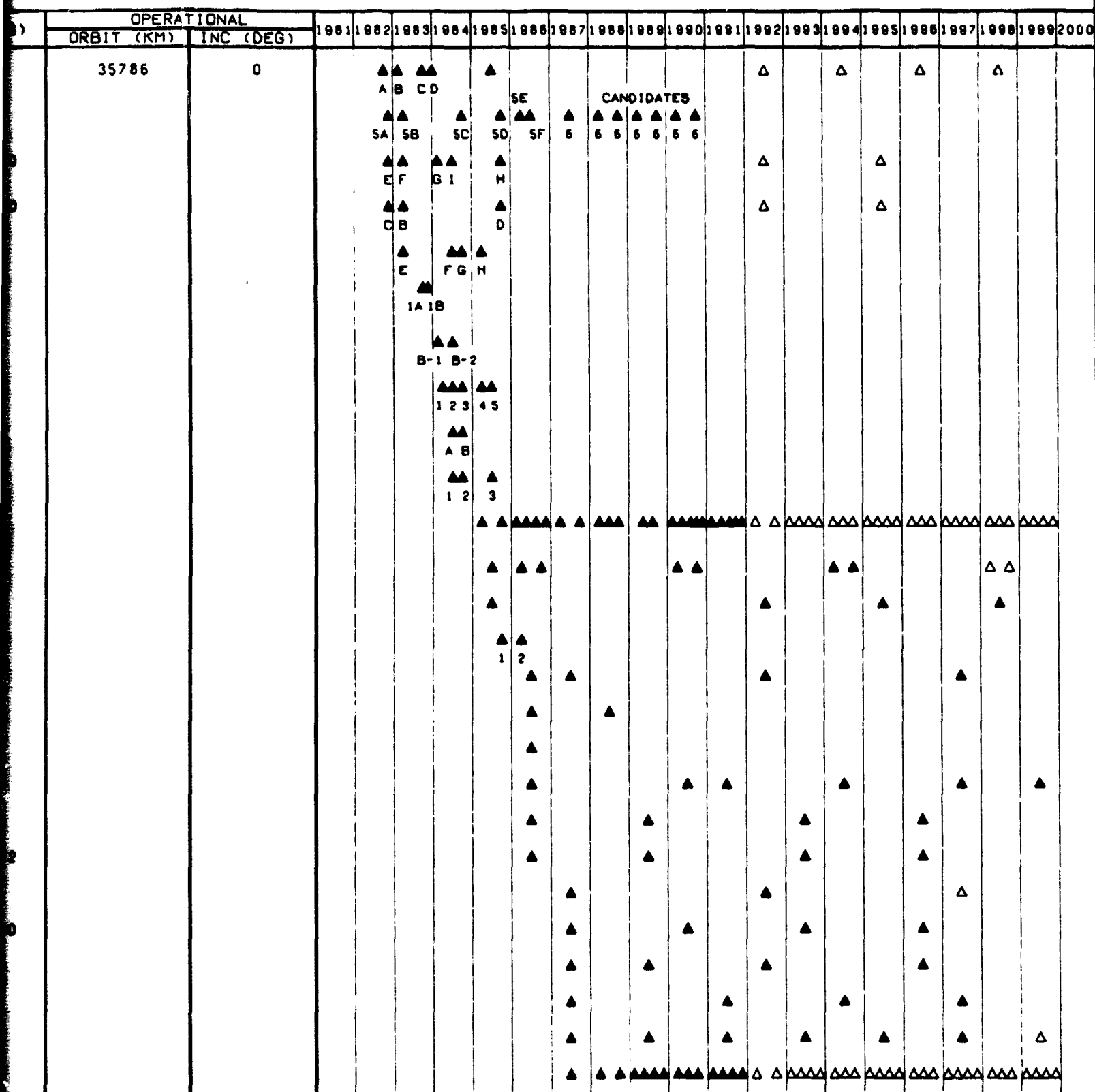
## GEO SATELLITE

SATELLITE	REF	SPONSOR	CAT.	MASS (KG)	OPERATIONAL	
					ORBIT (KM)	INC
TDRS	(C-1 & MDC)	WU	A	1905	35786	
INTELSAT	(AVN)	COM	A	1940		
INTELSAT	(AVN)	CAN.	A	1000-1130		
SAT.BUS.SYS	(MDC & AVN)	SBSC	A	1000-1130		
RCA	(AVN)	RCA	A	463		
INSAT	(AVN & MDC)	INDO	A	580		
PALAPA	(AVN)	INDS	A	944		
SYNCOM-IV	(AVN)	COM	A	1315		
ARABSAT	(AVN)	ARA	A	944		
AT&T	(AVN)	COM	A	944		
FOR.COMM/SBS	MDC	FOR.	C	615-726		
INMARSAT	MDC	FOR.	A	943		
GLOBAL DISASTER COMM	MDC	OAST	P	544		
PEOP REP CHINA	(AVN)	PRC	A	944		
GOES-GEO ORB.ENV SAT.	(E-2)	NOAA	P	720		
30/20 GHZ ANT. TRUNK	(C-4)	OSTA	P	1000		
SEPS-SOL ELECT. PROP	(T-9)	OST	P	3400		
RESOURCES/POLTN/WEATH/COM	(MDC)	OSTA	C	615-680		
FOREIGN COMM	(MDC)	FOR.	C	636-771		
EARTH OBS/COMMUN	(MDC)	OSTA	C	1413-1542		
STORMSAT	(MDC)	OSTA	C	1600		
EARTH OBS/COMMUN	(MDC)	OSTA	C	1821-2040		
EARTH OBS/COMMUN	(MDC)	OSTA	C	943-998		
MAP GRAVITY FIELD/COMM	(MDC)	OSS	C	615		
FOR.COMM/EARTH ORBS.	(MDC)	FOR.	C	943-998		
INMETSAT	(MDC)	FOR.	C	943		

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## GEO SATELLITES



**Fig. 2-4 Satellite and Services User Model (S/SUM) (Sheet 4 of 8)**

LEGEND

△ LAUNCH EVENT  
○ SERVICE EVENT  
▽ RETURN EVENT

SHADED : USER IDENTIFIED  
OPEN : ASSUMED

GEO SATELLITE

SATELLITE	REF	SPONSOR	CAT.	MASS (KG)	OPERATIONAL	
					ORBIT (KM)	INC (°)
US/FOR.COMM	(MDC)	FOR.	C	943-998	35786	0
FOREIGN COMM	(MDC)	FOR.	C	943-998		
RESOURCES/POLTN/WEATH//COMM	(MDC)	OSTA	C	667-726		
NATO IV	(MDC,DOD)	FOR/DOD	P	1057		
US COMM	(MDC)	COM	C	1575-2720		
THIN ROUTE SYS COMM	(C-6)	OSTA	O	2300		
RESOURCES/POLTN/WEATH/COMM	(MDC)	OSTA	C	943-998		
EARTH OBS/COMMUN	(MDC)	OSTA	C	1310-1360		
US COMM	(MDC)	COM	C	1450		
US COMM	(MDC)	COM	C	943-998		
ORBIT TRANS VEH	(T-10)	OSTA	P	4000		
SIMUL ASTRON MISSION	(GSF)	OSS	C	2075		
INT UV-XPLOR-F/O	(GSF)	OSS	C	500		
X-UV SPECTROSCOPY	(GSF)	OSS	C	1000		
GEO COMM PLAT STRUC	(C-5)	OSTA	P	6500		
FOREIGN COMM	(MDC)	FOR.	C	428-489		
FOREIGN COMM/EARTH OBS	(MDC)	FOR.	C	667-771		
ELECTRONIC MAIL	(MDC)	COM	O	2720		
PERSONAL COMM DEMO	(MDC)	COM	O	7250		
PUBLIC BROADCAST	(MDC)	COM	O	1814		
MANNED GEO SORTIE	(T-12)	OST	C	35,000		
EDUCATIONAL TV	(MDC)	COM	O	4535		
GRAVITY WAVE INTERFEROMETER (A-18,GAC)		OSS	O	80-100,000		
PERSONAL COMM ADV	(MDC)	COM	O	24,500		
ORBITING DEEP SPACE RELAY STA	(C-8)	OTDA	O	4300		
COSMIC-COHERENT OPT SYS	(A-20)	OSS	O	67,000		
100M THIN APERTURE TELESCOPE	(A-22)	OSS	O	85,000		
GEOSAT COMM PLAT FACIL	(MDC)	COM	O	8617		

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# GEO SATELLITES

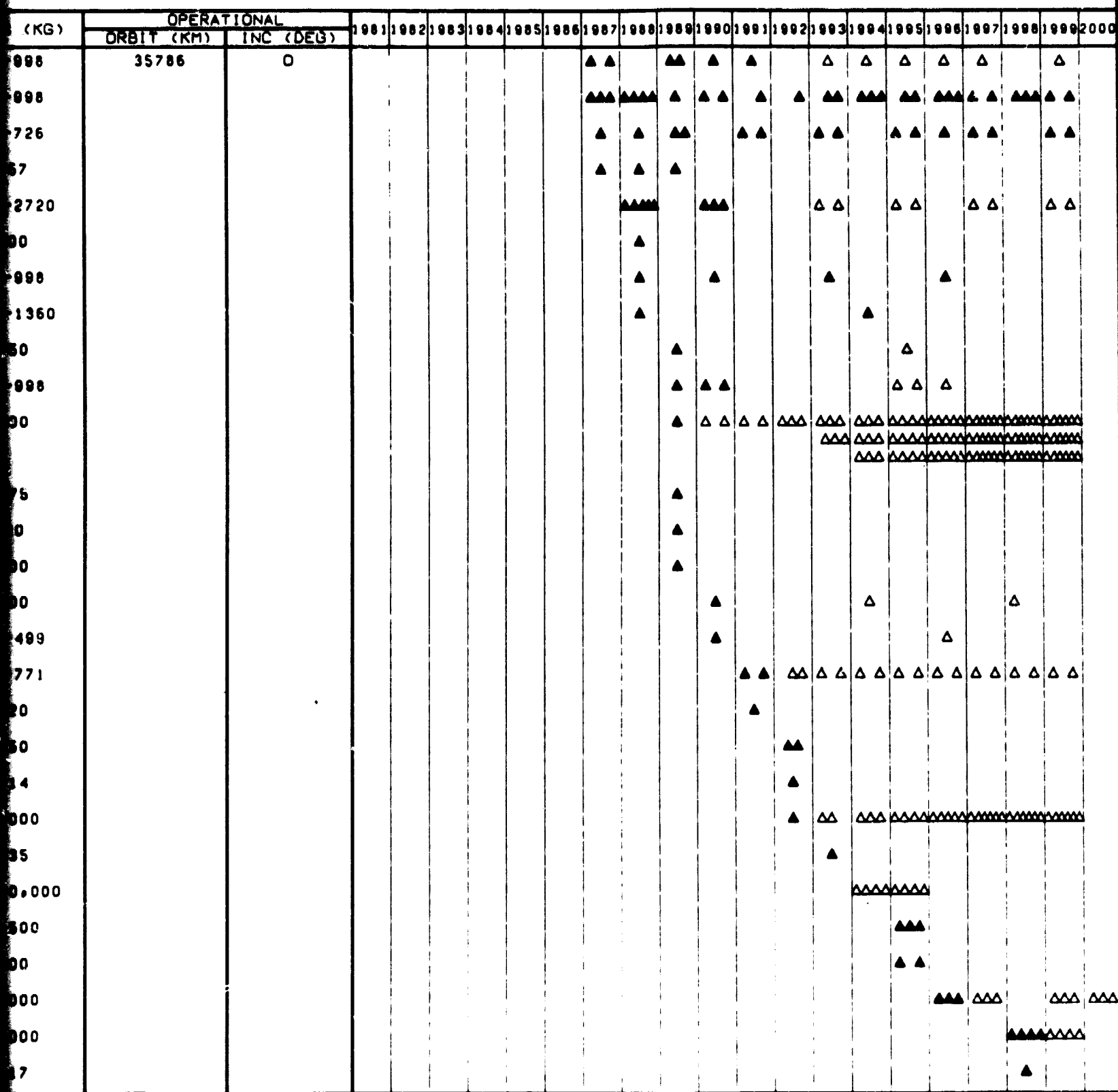


Fig. 2-4 Satellite and Services User Model (S/SUM)  
(Sheet 5 of 8)

LEGEND

▲ LAUNCH EVENT  
 ○ SERVICE EVENT  
 ▼ RETURN EVENT

SHADED : USER IDENTIFIED  
 OPEN : ASSUMED

PLANETARY/OTHER

SATELLITE	REF	SPONSOR	CAT.	MASS (KG)	OPERATIONAL	
					ORBIT (KM)	INC (°)
PLANETARY						
GALILEO ORBITER	(P-1)	OSS	A	1800	4RJ	
GALILEO PROBE	(P-1)	OSS	A	260	4RJ	
AMPT-ALT MAG PART EXPT	(S-6)	OSTA	A	1134	7RE	
HALLEY FLYBY	(P-3.5 YR)	OSS	P	3800	1.5AU	
INT SOLAR POLAR MISS. (A-3, S-3, FAM)		OSS/ESA	P	683	1.6AU	
VENUS ORBIT IMG RAD	(P-2)	OSS	P	1000	.72AU	
ORIGIN OF PLASMA	(S-7)	OSS	P	1000	240ER	
COMET RENDEZ	(P-3.5 YR)	OSS	P	3500	.72AU	
PLASMA TURB EXPLOR	(S-10)	OSS	C			
SOLAR PROBE	(S-11)	OSS	P	1500	4RS	
ADV INTERPLAN EXPLORER	(OSF)	OSS	C	1200	L <sub>1</sub>	
SATURN ORBIT (DUAL)	(P-4)	OSS	P	3000	9.5AU	
UNP PROG-URAN NEP PLUTO	(P-6)	OSS	C		49AU	
UNP PROG-URAN NEP PLUTO	(P-6)	OSS	C		49AU	
LUNAR POLAR ORBIT	(P-8)	OSS	O	300	400,000	
NR EARTH ASTEROID SAMPLE	(P-11)	OSS	O	4000	3AU	
ASTEROID MULT RENDEZ	(P-7)	OSS	O	2000		
MARS ADVANCE TECH	(P-5)	OSS	P	7000	.5AU	
EXTRATERRESTRIAL MATL PROC	(U-3)	OSTA	C			
NUCLEAR WASTE DISPOSAL	(MOC)	DOE	O	10430	.85AU	
UNP PROG-URAN NEP PLUTO	(P-6)	OSS	C			
LUNAR SAMPLE RET	(P-15)	OSS	O			
MERC ORBIT & LAND	(P-7)	OSS	O	500	.4AU	
GANYMEDE LANDER	(P-16)	OSS	O		5.2AU	
CLOSE SOLAR ORBITER	(S-15)	OSS	O		.1AU	
MARS ADV TECH (RETURN)	(P-5)	OSS	P		1.5AU	
NEAR EARTH ASTER (RET)	(P-11)	OSS	O		40AU	
VENUS LANDER	(P-12)	OSS	O	550	.72AU	
AUTO MOBILE LUNAR SURVEY	(P-13)	OSS	O	500		
COMET SAMPLE RETN	(P-10)	OSS	O	3500		
EXTRATERRESTRIAL INTELLIGENCE (L-3)		OSS	O		L3	
OTHER						
REFLIGHT OPP	(FAM)		P			
NASA FREE FLYER	(FAM)		P			
REFLIGHT OPP	(FAM)		P			
REFLIGHT OPP	(FAM)		P			
REFLIGHT OPP	(FAM)		P			
NASA FREE FLYER	(FAM)		P			

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## PLANETARY/OTHER

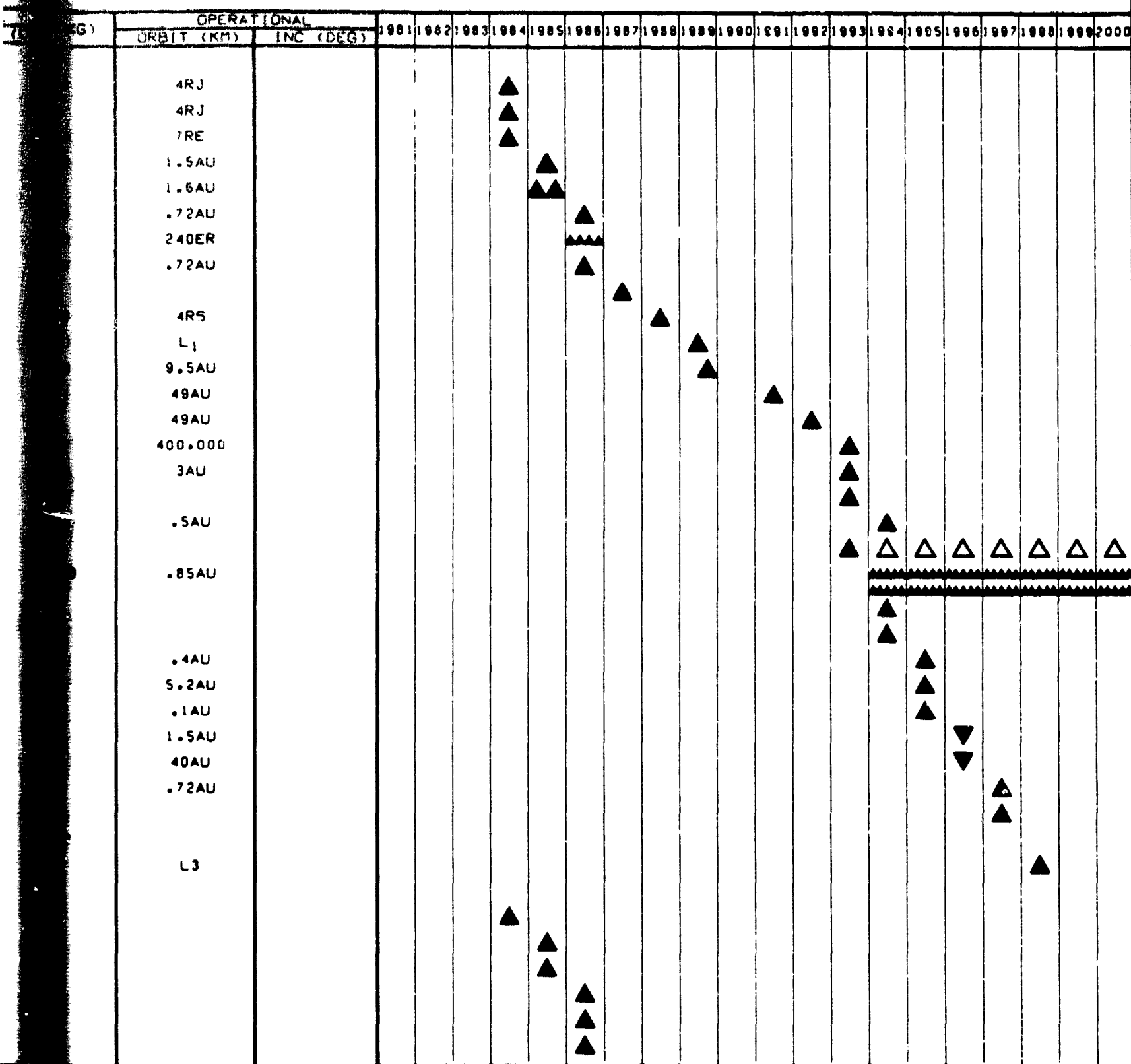


Fig. 2-4 Satellite and Services User Model (S/SUM) (Sheet 6 of 8)



LEGEND

- ▲ LAUNCH EVENT  
 ○ SERVICE EVENT  
 ▼ RETURN EVENT
- SHADED : USER IDENTIFIED  
 OPEN : ASSUMED

SORTIE MISSI

SATELLITE	REF	SPONSOR	CAT.	MASS (KG)	OPERATIONAL	
					ORBIT (KM)	INC (DEG)
IECM-INDUCED ENV CONTAMINATION	(FAM)		A	338	278	40.3
PDRS TEST ARTICLE	(FAM)	JSC	A		278	38
OSTA(SPACE & TERRESTAL APPLIC)	(FAM)	OSTA	A	680	278	28.5
SPAS-01	(IAF)	MBB	A	1800	296	28.5
SPACELAB-1 (VERIF & MULTIDISCIPLINE)	(AVN)	OSS	A	15800	250	57
TETHERED SATELLITE SYSTEM	(U-4)	OSTS	P	1500		
SPACELAB(SOLAR & ASTRO PHYSICS)	(FAM)	OSS	A	15000	374	57
MPS (MATERIAL PROCESSING)	(U-1)	OSTA	A		296	28.5
PEP.-PWR EXT PKG	(U-6)	JCS	A	950	296	28.5
SPACELAB-3(LOW GRAVITY)	(FAM)	ESA	A	15000	370	57
SPACELAB (LIFE SCIENCES)	(L-1, FAM)	ESA	A	14000	296	46
OSS (SPACE SCIENCES)	(FAM)	OSS	A		296	28.5
SPACELAB(BMFT)	(FAM)	ESA	A	15000	296	28.5
SPACELAB(SOLAR TERR)	(FAM)	OAST	A	15150	389	57
LARGE DEPLOY ANTENNA	(GAC)	OST	P	4700	74	28.5
SPACELAB (EARTH OBS)	(FAM)	OAST	A		370	57
SPACELAB (MATL PROC)	(FAM)	ESA	A	15300	296	28.5
SPACELAB-11 PLASMA	(FAM)	ESA	A			90
SIRTF-1R TELE FAC	(A-6)(2 PALLET)	OSS	P	2950	400	45
STARLAB TELESCOPE	(A-11,G)(2 PALLET)	OSS	P	2000	300	29
SOLAR SOFT X-RAY	(S-8)(1 PALLET)	OSS	P	1300	430	57
SPACELAB-PIN HOLE	(S-14)(1 PALLET)	OSTA	O	10000	370	97
LIDAR	(EI-47)(1 PALLET)	OSS	P			

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# SORTIE MISSIONS

NO. OF FLIGHTS  
OSS,OSTA OR SPACELAB NO. 3 2 NO. OF PALLETS  
STS-X FLT MANIFEST NO.

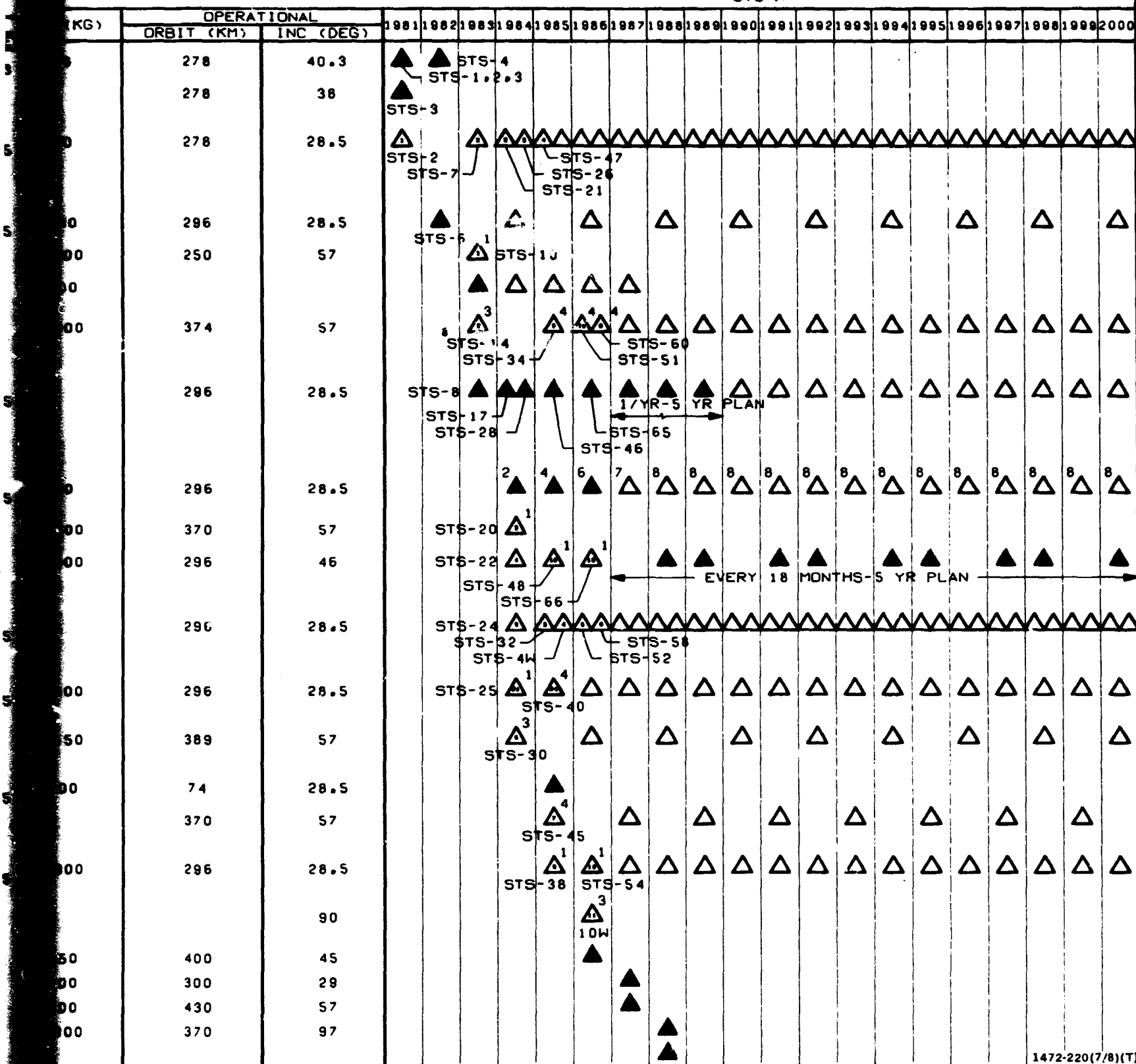


Fig. 2-4 Satellite and Services User Model (S/SUM)  
(Sheet 7 of 8)

LEGEND

△ LAUNCH EVENT  
○ SERVICE EVENT  
▽ RETURN EVENT

SHADED : USER IDENTIFIED  
OPEN : ASSUMED

DOD MISSIONS

SATELLITE	REF	SPONSOR	CAT.	MASS (KG)	OPERATIONAL	
					ORBIT (KM)	INC (DEG)
DOD 83-1	(FAM)	DOD				
DOD 83-2	(FAM)	DOD				
DOD 84-1	(FAM)	DOD				
DOD 84-2	(FAM)	DOD				
DOD 85-1	(FAM)	DOD				
DOD 85-2	(FAM)	DOD				
DOD 85-3	(FAM)	DOD				
DOD 85-4	(FAM)	DOD				
DOD 85-5	(FAM)	DOD				
DOD 85-6	(FAM)	DOD				
DOD 85-7	(FAM)	DOD				
DOD 85-8	(FAM)	DOD				
DOD 86-1	(FAM)	DOD				
DOD 86-2	(FAM)	DOD				
DOD 86-3	(FAM)	DOD				
DOD 86-6	(FAM)	DOD				
DOD 86-8	(FAM)	DOD				
DOD 86-10	(FAM)	DOD				
DOD 86-11	(FAM)	DOD				
P80-1-STP	(FAM)	DOD	A	4989	741	72
SPACE IR EXPERIMENT(SIRE) (DOD,MDC)		DOD	A	2487	741	98
GLOBAL POSITIONING SAT.(GPS) (DOD)		DOD	A	680-750	5886	63
TRANSIT (DOD)		DOD	A	164	1100	90
DEFENSE SAT.COMM SYS.(DSCS III)(DOD)		DOD	A	1057-1134	35786	0
SPACE TEST PROGRAM (STP) (DOD)		DOD	P	1000	500-1000	28.5-1
TALON GOLD-STP (DOD)		DOD	A	6800	296	28.5
DEFENSE MET.SAT.PGM (DMSP) (DOD)		DOD	A	2494-2721	243	98.7
MINI HALO-STP (DOD)		DOD	C	2268	35786	0

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FOR THE DIRECTOR

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**2-14**

2. 1942-1943 - 1943

- C** (Candidate) - Missions considered for possible initiation within ten years
- O** (Opportunity) - Potential missions for start beyond ten years and/or those missions of a speculative nature

These categories are consistent with the NASA OAST Space Systems Technology Model.

### 2.3 SERVICING EVENTS FREQUENCY

Figure 2-5 indicates the primary service functions associated with a service mission event and defines how the number of deployments and retrievals are determined for any given year in the S/SUM model. Namely, the total number of deployments equals the sum of initial launch deployments and revisit deployments; the total number of retrievals equals the sum of retrievals for revisit and retrievals for earth return. Within these definitions, an assessment of the frequency of service events, as depicted by the S/SUM model, was performed and is presented in Fig. 2-6.

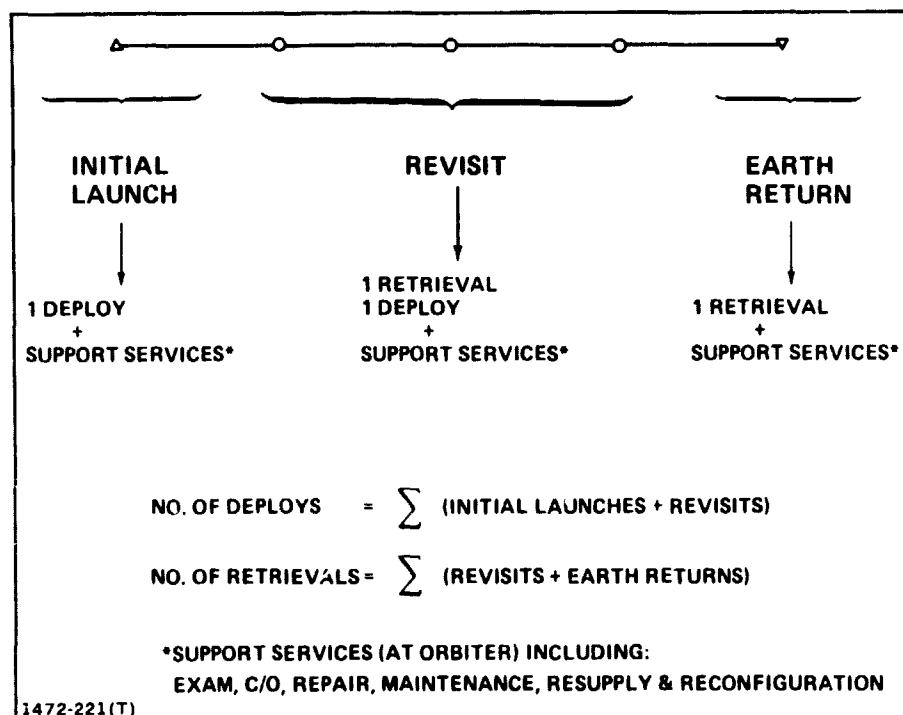
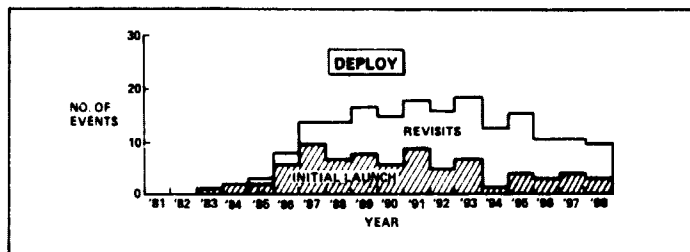


Fig. 2-5 Definitions Related to Service Frequency

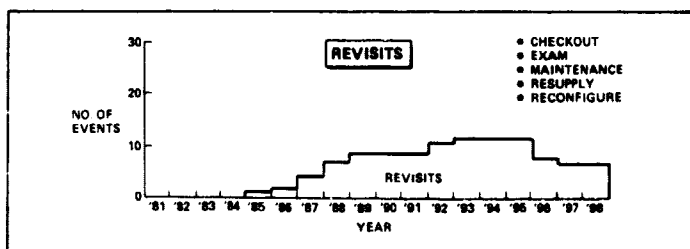
## SATELLITES WITH DIRECT DELIVERY/SERVICING BY THE ORBITER

THE FREQUENCY OF EVENTS FOR DEPLOYMENT AND REVISITS IS SHOWN. DEPLOYMENTS INCLUDE THOSE FOR INITIAL LAUNCH AND REDEPLOYMENTS THAT OCCUR FOLLOWING A REVISIT FOR SERVICING. DURING THE REVISITS, A VARIETY OF SERVICE FUNCTIONS COULD APPLY INCLUDING: CHECKOUT, EXAMINATION, RESUPPLY, AND RECONFIGURATION.

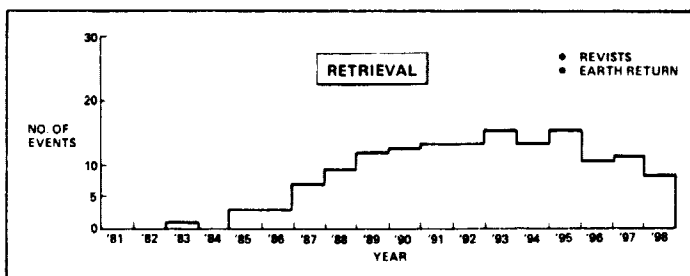


THE FREQUENCY OF EVENTS FOR DEPLOYMENT AND REVISITS IS SHOWN. FOR THIS SATELLITE CLASS, DEPLOYMENTS INCLUDE THOSE FOR INITIAL LAUNCH AND REDEPLOYMENTS THAT OCCUR FOLLOWING A REVISIT TO THE ORBITER FOR SERVICING.

SATELLITES WITH MASSES GREATER THAN 500 kg HAVE BEEN ASSUMED TO BE CANDIDATES FOR SERVICING AND RETRIEVAL. ADDITIONALLY, SERVICING REVISITS HAVE BEEN ASSUMED ON AN ANNUAL BASIS FOR THIS SATELLITE CLASS.

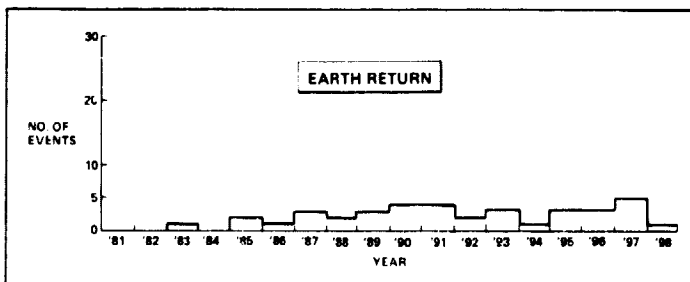


AS WITH THE DIRECT DELIVERY CLASS, SATELLITES GREATER THAN 500 kg ARE ASSUMED TO BE CANDIDATES FOR SERVICING AND RETRIEVAL. HOWEVER, THE SERVICING REVISIT INTERVAL (RETRIEVING/RETURNING THE SATELLITE TO THE ORBITER FOR SERVICING) HAS BEEN ASSUMED TO BE TWO YEARS IN THIS CASE.



THE FREQUENCY OF EVENTS FOR RETRIEVAL AND EARTH RETURN IS SHOWN. RETRIEVALS INCLUDE THOSE THAT OCCUR DURING A REVISIT AND FOR AN EARTH RETURN SITUATION. NOTE THAT THE RETRIEVAL FREQUENCY BEGINS TO BUILD IN THE 1986 TIME PERIOD WHILE EARTH RETURNS REMAIN FAIRLY CONSTANT.

THE FREQUENCY OF RETRIEVALS AND EARTH RETURNS FOR THE LEO/PROPULSION GROUP OF SATELLITES IS SHOWN. IN ADDITION TO RETRIEVALS REQUIRED FOR SERVICING REVISITS, A RETRIEVAL IS REQUIRED FOR EACH EARTH RETURN. AGAIN, NOTE THAT THE DEMAND FOR RETRIEVALS BEGINS TO BUILD IN THE 1986 TIME PERIOD AND EARTH RETURNS REMAIN FAIRLY LEVEL.

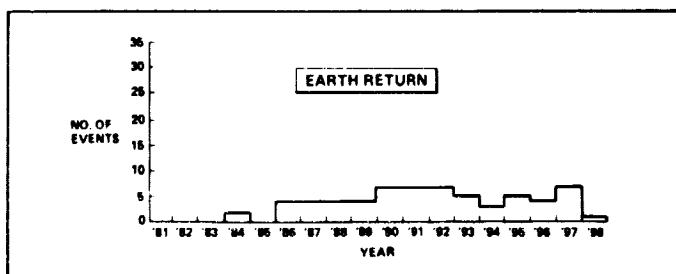
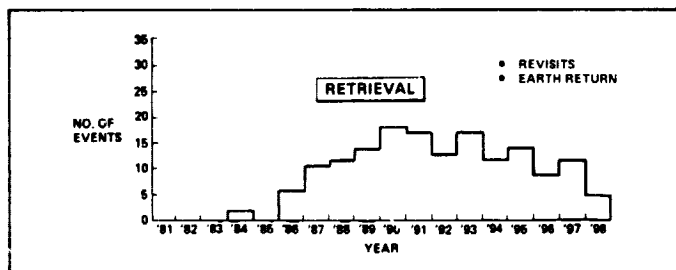
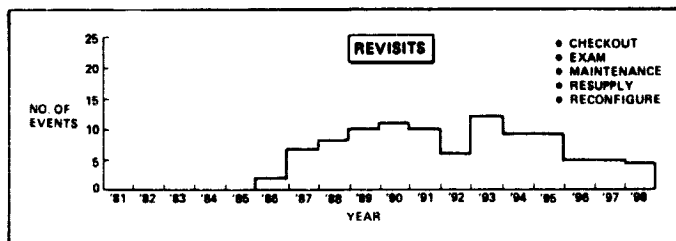
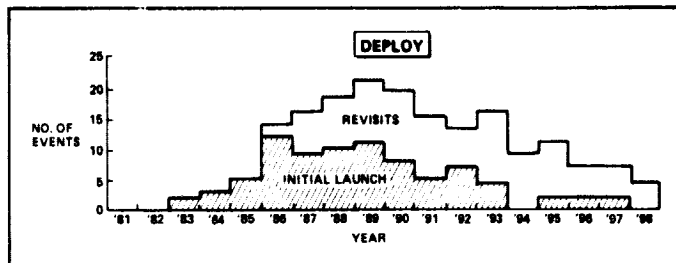


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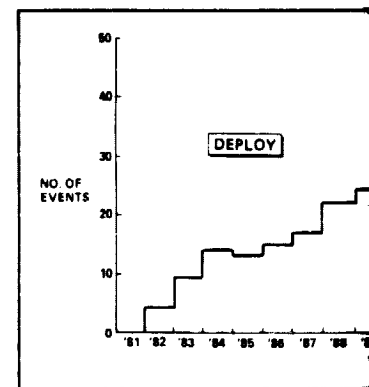
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# SATELLITES WITH LEO PROPULSION

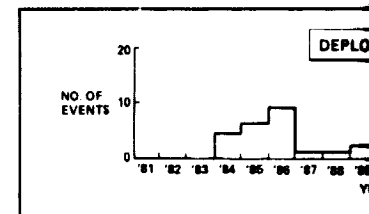


THE FREQUENCY OF DEPLOYMENT EVENTS FOR SATELLITES DESTINED FOR GEOSYNCHRONOUS ORBIT IS SHOWN. AS INDICATED PREVIOUSLY, THIS SATELLITE CLASS DOES NOT INCLUDE DoD SATELLITES. CLEARLY, THE MODEL REFLECTS CONSIDERABLE TRAFFIC TO GEO AS A FUNCTION OF TIME, WITH OTV/MOTV TRAFFIC BUILDING IN THE 1990s.

## GEO SATELLITES

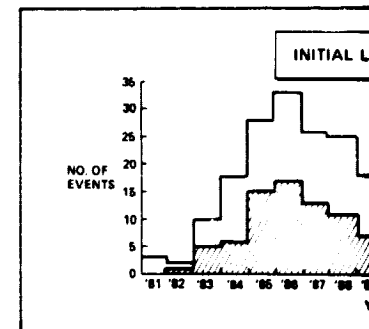


## PLANETARY/OTHER



THE FREQUENCY OF DEPLOYMENT EVENTS IS SHOWN FOR SPACECRAFT DESTINED FOR PLANETARY ENVIRONS ("OTHERS" ARE MINIMAL AND, THEREFORE, NEGLECTED). A MODEST TRAFFIC LEVEL IS PROJECTED WITH THE PRIMARY ACTIVITY IN THE 1990s ATTRIBUTED TO NUCLEAR WASTE DISPOSAL TRAFFIC.

## SORTIES/DoD

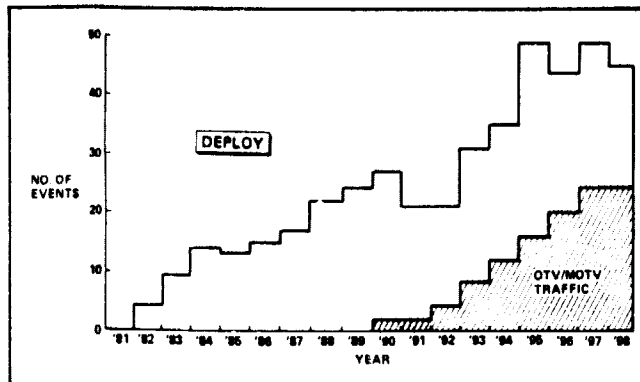


PAYLOADS IN THE SORTIES/DoD CLASS ARE SHOWN. DoD LAUNCHES (PAYLOADS UNIDENTIFIED) APPEAR TO MAINTAIN A FAIRLY STEADY FREQUENCY LEVEL DURING THE TIME PERIOD INDICATED. IN GENERAL, A FAIRLY LEVEL SORTIE ACTIVITY IS EXPECTED THROUGH THE NEXT TWO DECADES.

Fig. 2-6 Service

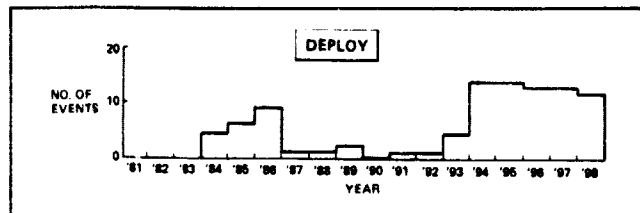
### GEO SATELLITES

THE FREQUENCY OF DEPLOYMENT EVENTS FOR SATELLITES DESTINED FOR GEOSYNCHRONOUS ORBIT IS SHOWN. AS INDICATED PREVIOUSLY, THIS SATELLITE CLASS DOES NOT INCLUDE DoD SATELLITES. CLEARLY, THE MODEL REFLECTS CONSIDERABLE TRAFFIC TO GEO AS A FUNCTION OF TIME, WITH OTV/MOTV TRAFFIC BUILDING IN THE 1990s.



### PLANETARY/OTHERS

THE FREQUENCY OF DEPLOYMENT EVENTS IS SHOWN FOR SPACECRAFT DESTINED FOR PLANETARY ENVIRONS ("OTHERS" ARE MINIMAL AND, THEREFORE, NEGLECTED). A MODEST TRAFFIC LEVEL IS PROJECTED WITH THE PRIMARY ACTIVITY IN THE 1990s ATTRIBUTED TO NUCLEAR WASTE DISPOSAL TRAFFIC.



### SORTIES/DoD

PAYLOADS IN THE SORTIES/DoD CLASS ARE SHOWN. DoD LAUNCHES (PAYLOADS UNIDENTIFIED) APPEAR TO MAINTAIN A FAIRLY STEADY FREQUENCY LEVEL DURING THE TIME PERIOD INDICATED. IN GENERAL, A FAIRLY LEVEL SORTIE ACTIVITY IS EXPECTED THROUGH THE NEXT TWO DECADES.

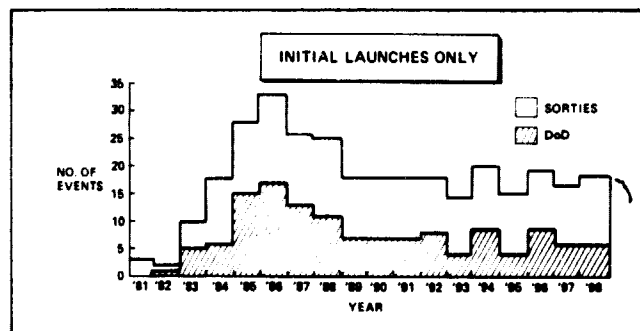


Fig. 2-6 Servicing Events Frequency



## 2.4 SERVICING EVENTS SUMMARY

The frequency of mission events, as a function of time, for all of the S/SUM satellite classes (exclusive of Sorties/DoD), is shown in Fig. 2-7. Initial launch and earth return events are (singularly) indicated when they occur; revisit events represent planned maintenance activities. Satellites with masses greater than 500 kg have been assumed to be candidates for servicing and retrieval, both for Direct Delivery/ Servicing and for LEO/Propulsion satellite classes. Servicing revisits, however, have been assumed on an annual basis for the Direct Delivery/Servicing class, and at two year intervals for the LEO/Propulsion class satellites.

As indicated in Fig. 2-7, mission events and their service needs grow to approximately 70 service events in the 1988 time-frame and remain fairly-level through the early 1990s. Exclusive of initial launch/deployment, the need for revisit services begins to accelerate in 1986.

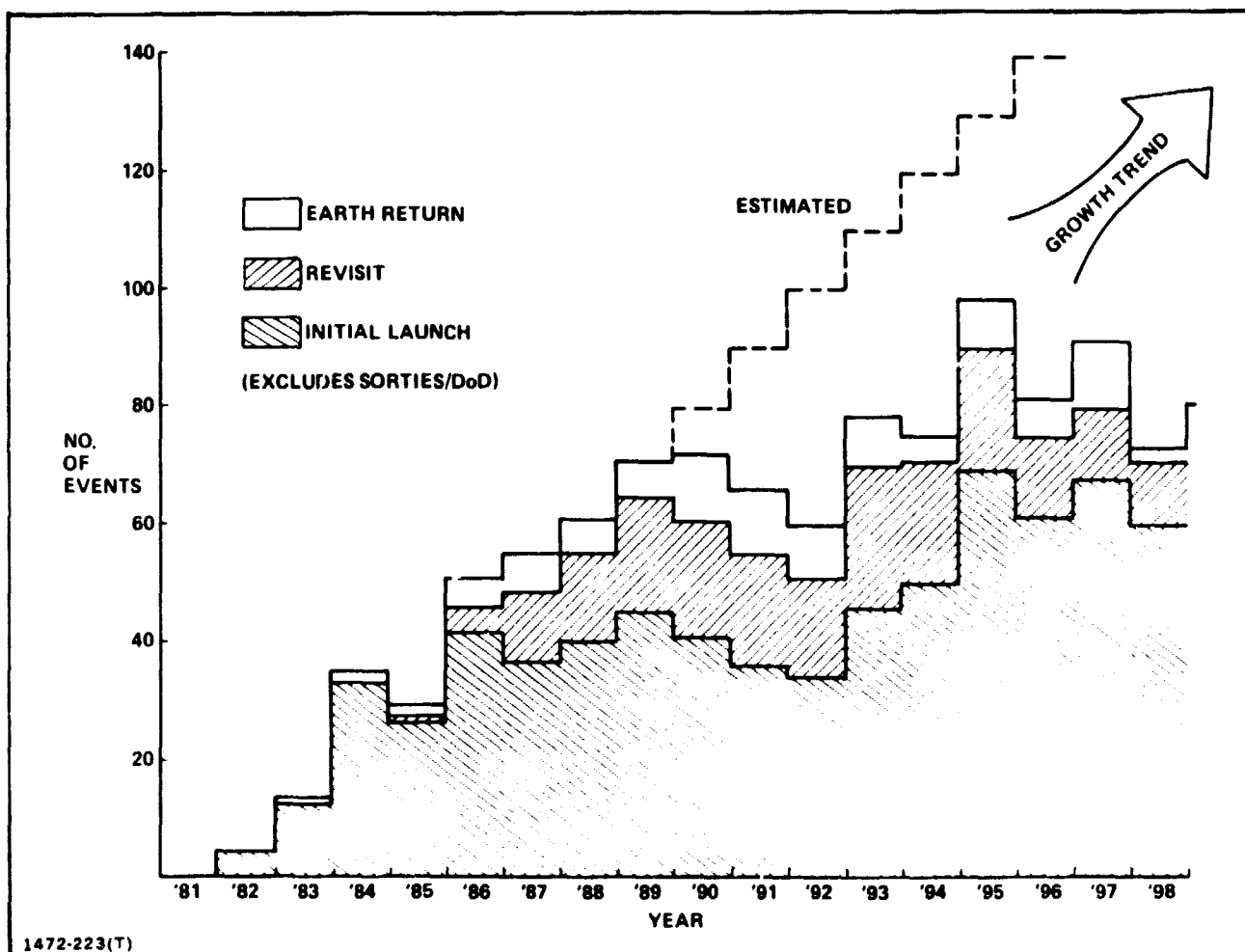


Fig. 2-7 Satellite and Services User Model - Mission Events

Furthermore, in the 1986 to 1990s time period, approximately three times as many launch events are projected compared to revisit/earth return events. Since present Shuttle manifesting generally accommodates nearly three payloads per Shuttle launch, it appears that revisit/earth return services could be planned for Orbiter flights after initial launch/deployment of satellite payloads has been accomplished. This would avoid the necessity of scheduling dedicated revisit or earth return missions for other than "special situations." Figure 2-8 summarizes the frequency of mission events by satellite classes. The chart indicates that, during the 1985-1995 time period, overall service need levels are about the same for Direct Delivery, LEO/Propulsion, and GEO satellite classes.

Interestingly, even though very few satellites/payloads currently exist in the 1990s phase of the S/SUM model, the service need level still remains high through the 1990s. Clearly, as new satellite programs evolve for that time period, the trend for potential service needs will continue to grow. It would appear, therefore, that our "stable of satellite candidates" for the 1980s should represent reasonable baselines upon which to develop potential service needs and to formulate servicing concepts (including hardware and operations), with a view toward potential standardization.

Additionally, the S/SUM model does not reflect the impact of backup/contingency or unscheduled service needs. Our projections could, therefore, be considered conservative.

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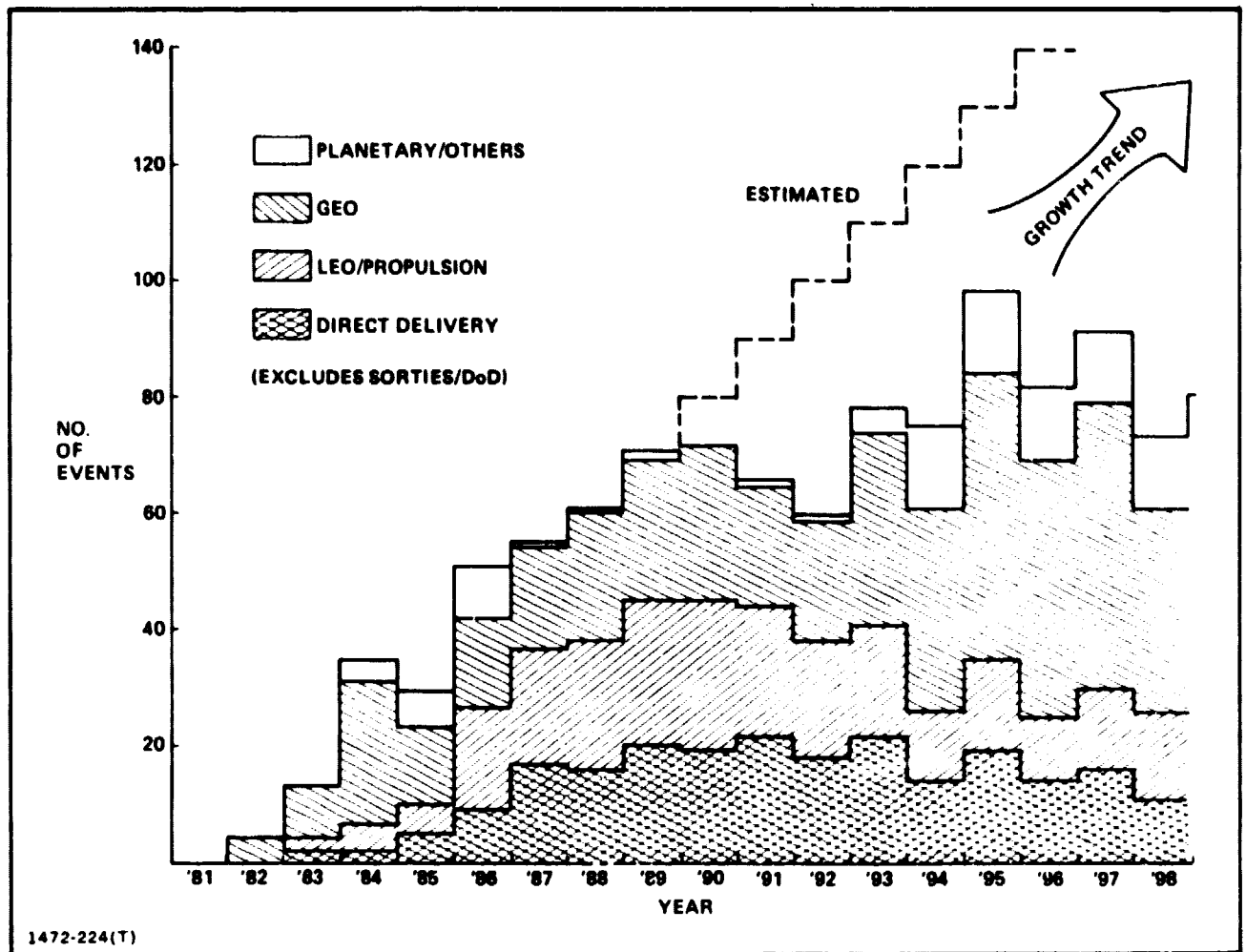


Fig. 2-8 Satellite and Services User Model – Satellite Classes/Mission Events

## **2.5 S/SUM SENSITIVITY ANALYSIS**

This subsection presents the results of a sensitivity analysis that was performed to assess the implications of various programmatic and operational factors on the need for satellite services.

### **2.5.1 Programmatic Sensitivity Factors**

The following factors were considered in this analysis:

- How the projected demand for service needs is affected by considering only highly-probable satellite programs (Approved and Planned)
- Quantity of projected service traffic associated with conventional satellites
- Quantity of LEO/Propulsion traffic (above the Orbiter's nominal delivery altitude) captured by the introduction of a propulsion stage in 1988
- Number of satellite programs that are candidates for servicing with the introduction of a Space Operations Center (SOC) in 1990.

By considering only the Approved and Planned satellite programs, an insight is provided into the "minimal-likely" service traffic that might be anticipated.

As addressed herein, the "conventional satellites" designation does not consider large or special purpose satellite platforms such as large space structures, Solar Power Satellite test articles, Science and Applications Space Platforms, and the 25 kW Power module.

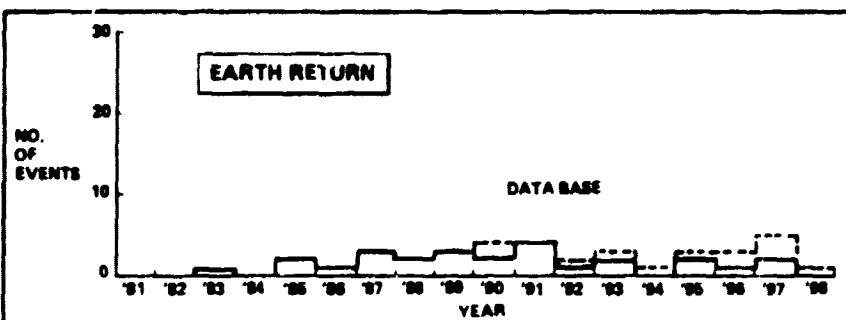
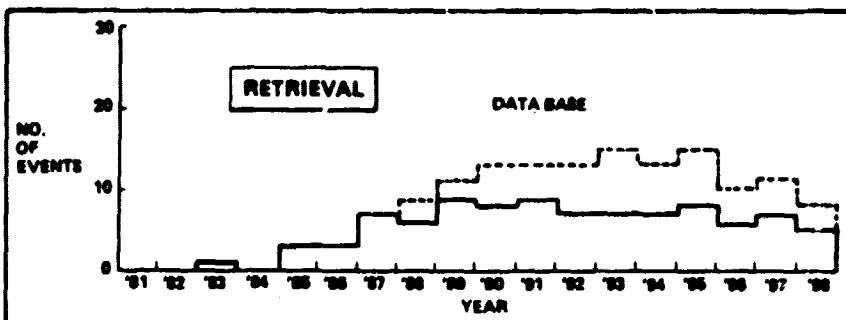
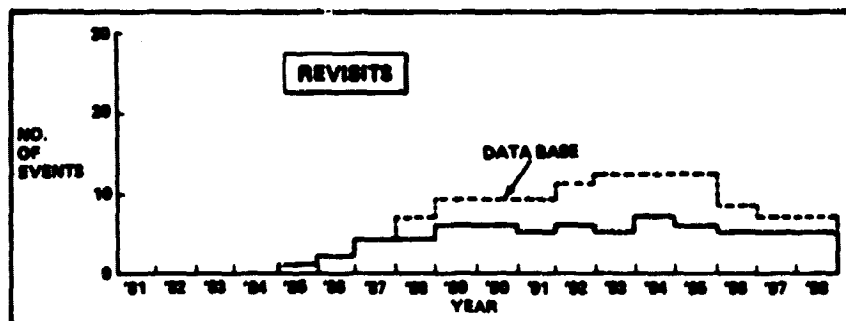
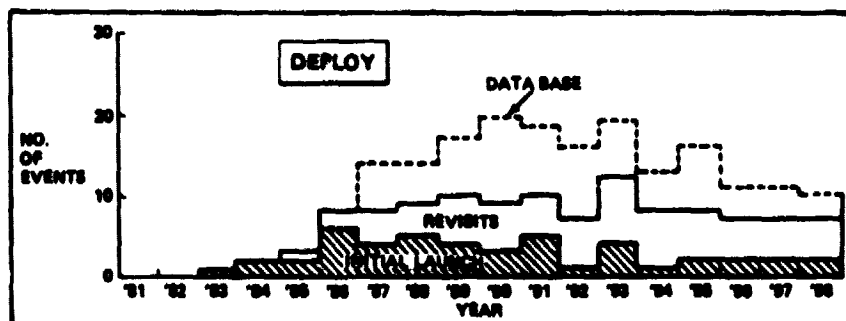
The availability of a propulsion stage in 1988 would effect planned or contingency servicing of satellites that are not directly reachable by the Orbiter. Obviously, satellites that are not equipped with their own propulsion capabilities (to lower their orbit altitude) could not be visited for servicing or retrieved for earth return.

SOC was assumed to become operational in 1990 and enables planned and contingency repair/servicing to all LEO satellites at inclinations of 28.5 degrees.

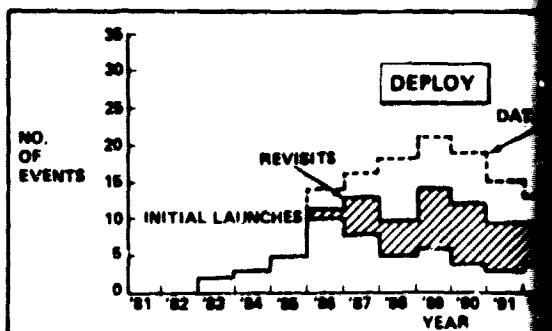
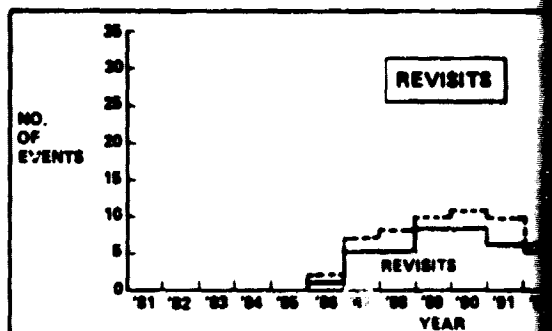
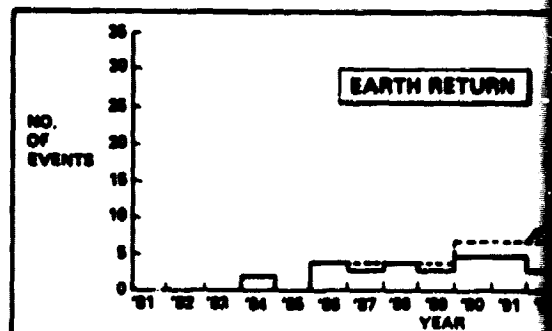
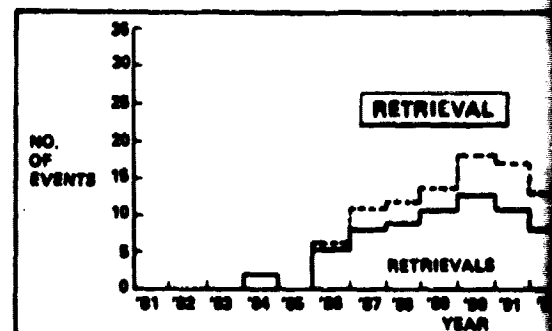
### **2.5.2 Approved/Planned Satellite Programs' Effect on Service Needs**

Figure 2-9 compares the servicing events frequency for Approved/Planned satellite programs to the data base of total events in the S/SUM model. For the Direct Delivery/Servicing satellite class, more than half the service events projected in the total model are for Approved and Planned satellite programs. The LEO/Propulsion class reflects an even higher proportion of satellites in the same category. For both classes,

# SATELLITES WITH DIRECT DELIVERY/SERVICING BY THE ORBITER



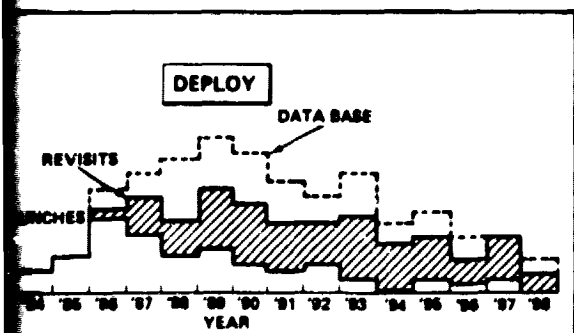
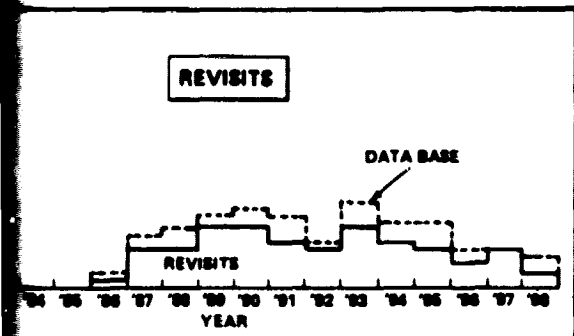
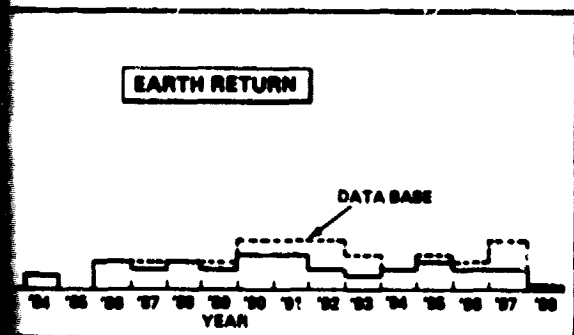
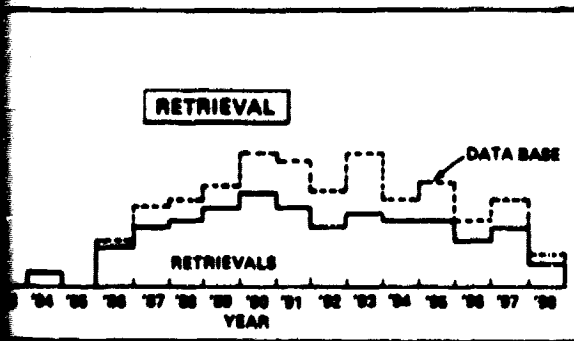
# SATELLITES WITH LEO PROPULSION



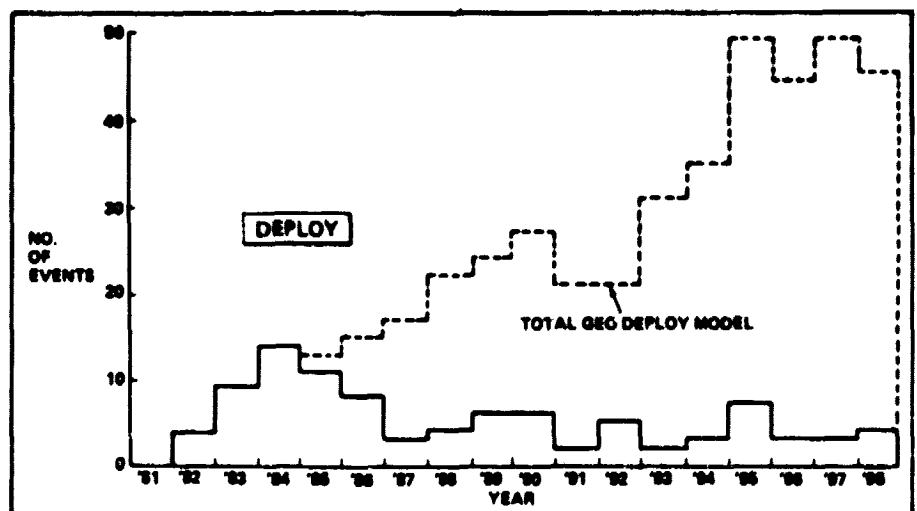
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# SATELLITES WITH LEO PROPULSION



## GEO SATELLITES



## PLANETARY/OTHERS

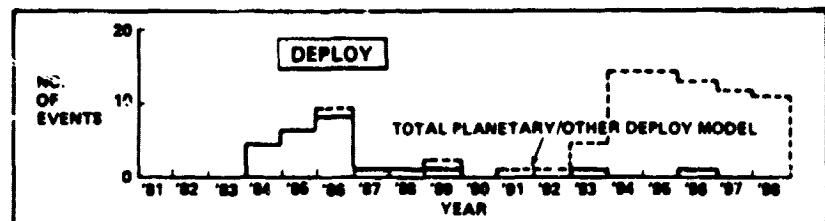


Fig. 2-9 Servicing Events Frequency -- Approved/Planned Satellite Programs

note that the frequency of service events again begins to accelerate in the 1986 time frame.

The GEO satellite class indicates that the frequency of service events for Approved/Planned programs dominates the mid-1980s, with few programs in the Approved/Planned category presently appearing in the out-years of the model. This is to be expected, as our total S/SUM model assumes a growth in GEO traffic with many satellite programs still in the "not-firm" status.

The Planetary/Other satellite class shows a close correlation to the total data base in the mid-1980s (in terms of Approved/Planned programs) and a wide divergence in the out-years. This is largely due to the introduction of a nuclear waste disposal system in the 1990s (in the S/SUM) which, of course, is not in the Approved/Planned category.

A summary of the major service events for the close-in 5 year interval of 1983-1988 (see Fig. 2-10) compares the total S/SUM model to Approved/Planned satellite programs. First, a similarity between the major service events can be noted for the Direct Delivery/Servicing and LEO/Propulsion class satellites. Secondly, when comparing Approved/Planned events to the total model (in the 1983-1988 time frame), the S/SUM model clearly reflects a large number of Approved/Planned satellite programs. Planned satellite programs.

### 2.5.3 Sensitivity Summary

Figure 2-11 summarizes the number of satellite programs affected by the programmatic or operational factors considered herein.

#### 2.5.3.1 Approved & Planned (A/P) Satellite Programs - For satellites with *Direct Delivery/Servicing* by the Orbiter:

- 29 satellite programs in the S/SUM are candidates for deployment and backup retrieval/redeployment, 17 of which are in the A/P category
- 29 satellite programs in S/SUM are candidates for unscheduled maintenance/repair and 13 of these are in the A/P category
- 20 satellite programs in S/SUM are candidates for planned maintenance/repair and 10 of the 20 are of the A/P category
- 21 satellite programs in S/SUM are candidates for earth return and 10 of these are in the A/P category

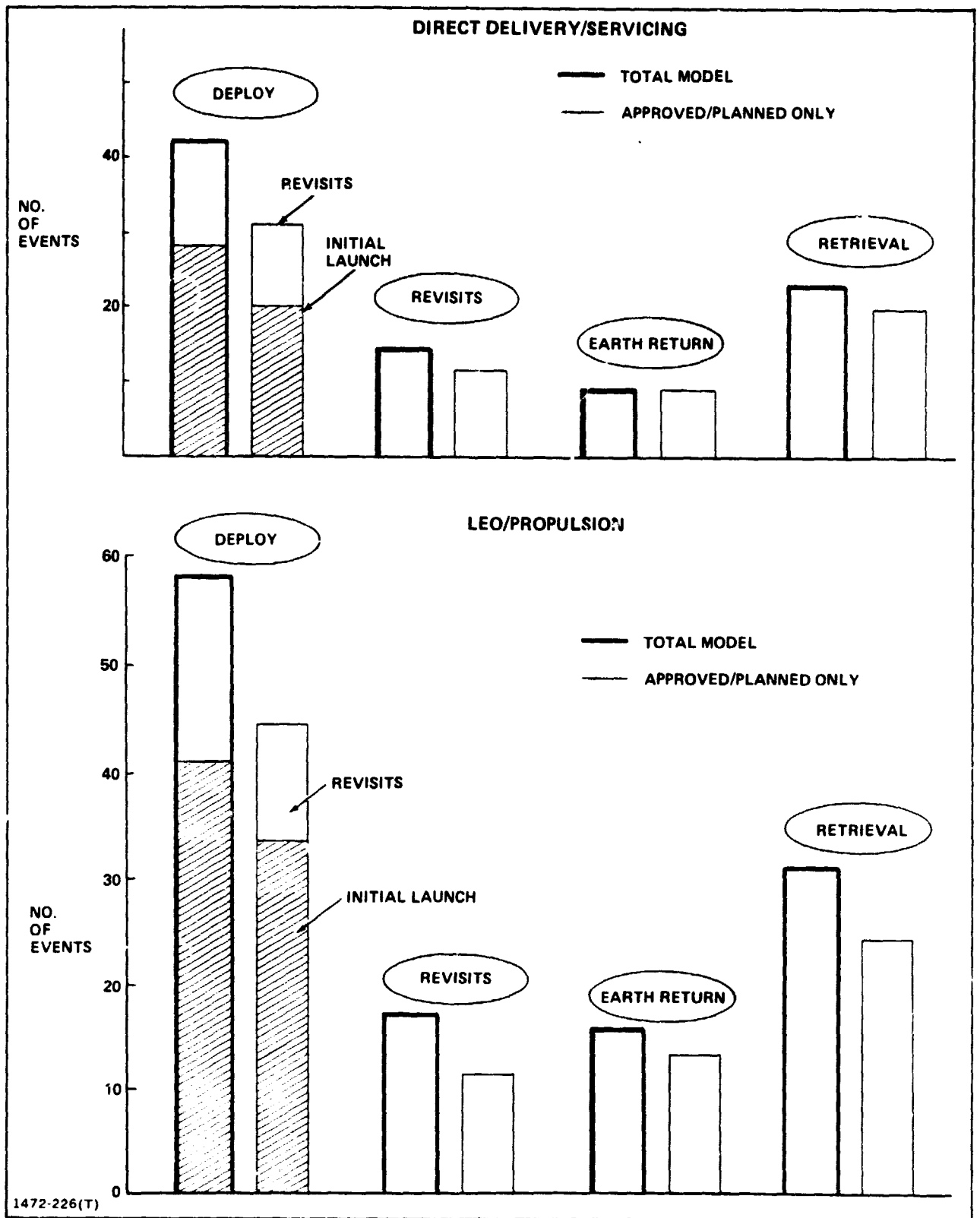


Fig. 2-10 Comparison of Servicing Events in 1983-1988 Time Frame



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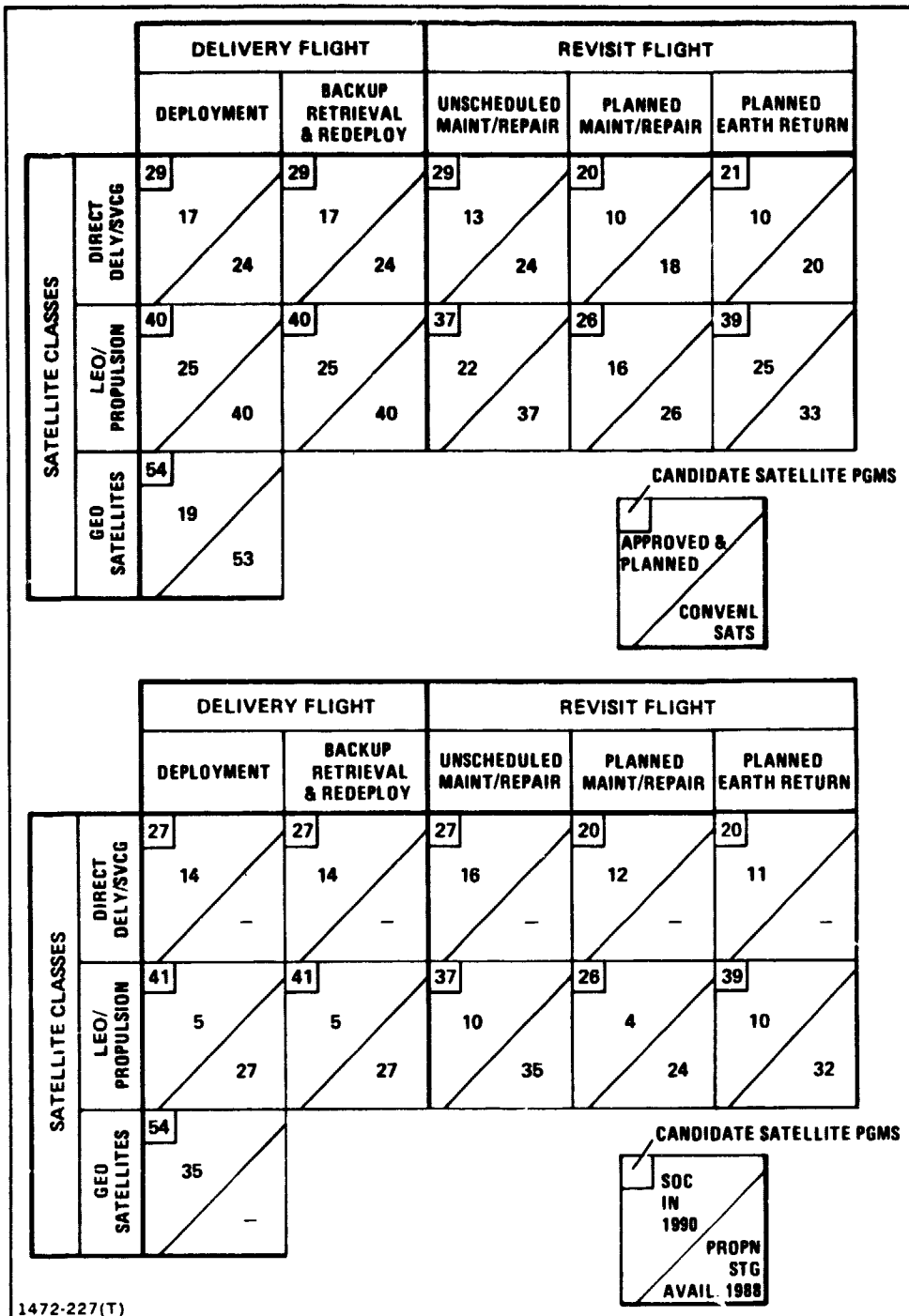


Fig. 2-11 S/SUM - Sensitivity Summary

For satellites with LEO Propulsion:

- 40 satellite programs in S/SUM are candidates for deployment and backup retrieval/redeployment; 25 of these are in the A/P category
- 37 satellite programs in S/SUM are candidates for unscheduled maintenance/repair and 22 are in the A/P category
- 26 satellite programs in S/SUM are candidates for planned maintenance/repair and 16 are in the A/P category
- 39 satellite programs in S/SUM are candidates for earth return and 25 are in the A/P category.

For *Geosynchronous satellites*, 54 satellite programs in the S/SUM are candidates for deployment, 19 of which are in the A/P category.

**2.3.3.2 Conventional Satellites - For satellites with *Direct Delivery/Servicing Orbiter*:**

- 29 satellite programs in S/SUM are candidates for deployment, backup retrieval/redeployment, and unscheduled maintenance/repair; 24 of the total are conventional satellites
- 20 satellite programs in S/SUM are candidates for planned maintenance/repair and 18 are conventional satellites
- 21 satellite programs in S/SUM are candidates for earth return and 20 are conventional satellites

All satellites with *LEO Propulsion* are conventional satellites:

- 40 satellite programs in S/SUM are candidates for deployment and backup retrieval/redeployment
- 37 satellite programs in S/SUM are candidates for unscheduled maintenance/repair
- 26 satellite programs in S/SUM are candidates for planned maintenance/repair
- 39 satellite programs in S/SUM are candidates for earth return.

For *Geosynchronous satellites*, 54 satellite programs are candidates for deployment, 53 of which are conventional satellites.

#### **2.3.3.3 Propulsion Stage Availability in 1988 - For satellites with *LEO Propulsion*:**

- 41 satellite programs in the S/SUM are candidates for deployment and backup retrieval/redeployment; 27 of these programs could be handled by the propulsion stage
- 37 satellite programs in S/SUM are candidates for unscheduled maintenance/repair and 35 of these programs could be serviced by the propulsion stage
- 26 satellite programs in S/SUM are candidates for planned maintenance/repair and 24 of these programs could be serviced by the propulsion stage
- 39 satellite programs in S/SUM are candidates for earth return and 33 of these programs could be supported by the propulsion stage.

#### **2.3.3.4 Space Operations Center (SOC) Operational in 1990 - For satellites with *Direct Delivery/Servicing* by the Orbiter:**

- 27 satellite programs in S/SUM are candidates for deployment and backup retrieval/redeployment, 14 of which could be accommodated by SOC operations
- 27 satellite programs in S/SUM are candidates for unscheduled maintenance/repair, 16 of which could be accommodated by SOC operations
- 20 satellite programs in S/SUM are candidates for planned maintenance/repair, 12 of which could be accommodated by SOC operations
- 20 satellite programs in S/SUM are candidates for earth return, 11 of which could be accommodated by SOC operations.

For satellites with *LEO Propulsion*:

- 41 satellite programs in S/SUM are candidates for deployment and backup retrieval/redeployment; 5 of which could be accommodated by SOC operations
- 37 satellite programs in S/SUM are candidates for unscheduled maintenance/repair and 10 could be accommodated by SOC operations
- 26 satellite programs in S/SUM are candidates for planned maintenance/repair; 4 of the 26 could be accommodated by SOC operations
- 39 satellite programs in S/SUM are candidates for earth return and 10 of them could be accommodated by SOC operations.

For *Geosynchronous satellites*, 54 satellite programs are candidates for deployment, 35 of which could be accommodated by SOC operations.

### 3 - REFERENCE SATELLITE SELECTION

To guide the development of service equipment concepts, a number of reference satellites were selected from the S/SUM spacecraft listing. Figure 3-1 summarizes the number of satellites affected by various servicing events as related to the major satellite classes. Reference satellites that reflect a spectrum of servicing needs have been selected as baselines to develop service equipment concepts.

		DELIVERY FLIGHT		REVISIT FLIGHT		
		DEPLOYMENT	BACKUP RETRIEVAL & REDEPLOY	UNSCHEDULED MAINT/REPAIR	PLANNED MAINT/REPAIR	PLANNED EARTH RETURN
SATELLITE CLASSES	DIRECT DELY/SVCG	29	29	27	20	21
	LEO/ PROPULSION	40	40	37	26	39
	GEO SATELLITES	54	THE BASE FOR SELECTION OF DESIGN REFERENCE SATELLITES			

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Fig. 3-1 Satellite Classes vs Servicing Events

#### 3.1 SELECTION FACTORS

The following criteria were used to select design reference satellites:

- Time frame
- Mass
- Configuration variability
- Extent of potential service needs
- Stabilization (spin/3-axis)
- Contamination sensitive

- Deployable appendages
- Candidates in 1983 to 1993 time period, (favoring approved/planned).

Factors such as mass, configuration variability, and deployable appendages are important to ensure that servicing techniques are applicable to a broad range of potential users. Satellite contamination sensitivity is also an important issue, since it may require Orbiter stand-off for retrieval and special considerations for Orbiter-attached servicing operations. Other selection factors depend upon program priority and the extent of servicing required (or of potential benefit).

### 3.2 REFERENCE SATELLITES & FEATURES

Figure 3-2 identifies reference satellites selected for the study. Ten of the thirteen reference satellites are approved or in the planning stage, and represent highly probable satellite programs. The remaining three reference satellites are categorized as candidate programs and were chosen to ensure that proper consideration is given to a time-phased growth in servicing capabilities through the 1980s. As a group, the satellites encompass a wide range of mass and size, some of which could be sensitive to Orbiter outgassing and contamination.

All LEO satellite selections are presently considering the incorporation of satellite services as part of their nominal operations; two include on-orbit support services for extended mission durations. The reference GEO satellites include both SSUS and IUS propulsion stage operations.

All satellite selections are in the early definition phases, some (GRO) have commenced alternate concept definition studies. In addition, several reference satellites are likely candidates for the MMS spacecraft bus and, therefore, are considered receptive to the inclusion of future servicing requirements in their designs.

Figure 3-3 identifies the four reference satellites for the direct delivery/servicing class and their corresponding delivery/revisit schedules. Satellite programs presently considering Orbiter launch, revisit, and retrieval are identified by solid symbols, and open symbols represent assumptions made in the S/SUM. A broad range of mission events and service needs is reflected in the selections.

Figure 3-4 illustrates spacecraft configurations of reference satellites for the direct delivery/servicing class. Satellite masses range from 1600 to 10,000 kg and represent a considerable variation in size and configuration.

CATEGORY	PLANNED SERVICE NEEDS										STABILIZATION	CONTAM SENS	SPONSORING ORG
	DEPLOY												
	EXAMINE	RETRIEVE	CHECKOUT	EARTH RETURN	MAINTAIN	RECONFIGURE	RESUPPLY	LARGE	INTERMEDIATE	SMALL	DEPLOY APPENDAGES	MASS	
DIRECT DELIVERY SATS													
GAMMA RAY OBSERVATORY	'85	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	OSS
LASSII	'86	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	NRL
GRAVSAT A	'86	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	OSS
ADV X-RAY ASTROPHYS FACIL	'87	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	OSS
LEO/PROPULSION SATS													
SOLAR MAX MISSION RETRIEVAL	'84	✓	✓	✓	✓	✓	✓	✓	✓	✓	STAB.	✓	OSS
LANDSAT D"	'85	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	NOAA
NATIONAL OCEANIC SAT. SYST	'86	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	DOD
UPPER ATMOSPHERE RES SAT.	'86	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	OSTA
X-RAY TIMING EXPLORER	'86	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	OSS
GEOSYNCHRONOUS SATS													
INTELSAT	'85	✓	✓	✓	✓	✓	✓	✓	✓	✓	SPIN	✓	COMM
SIMUL TANEIOUS ASTRON MISS.	'89	✓	✓	✓	✓	✓	✓	✓	✓	✓	3 AXIS	✓	OSS
INACTIVE SATELLITES/DEBRIS													
DAO-1	'88	✓	✓	✓	✓	✓	✓	✓	✓	✓	TUMBLING	✓	OSS
LARGE OBJECTS	'88	✓	✓	✓	✓	✓	✓	✓	✓	✓	TUMBLING	✓	OSS

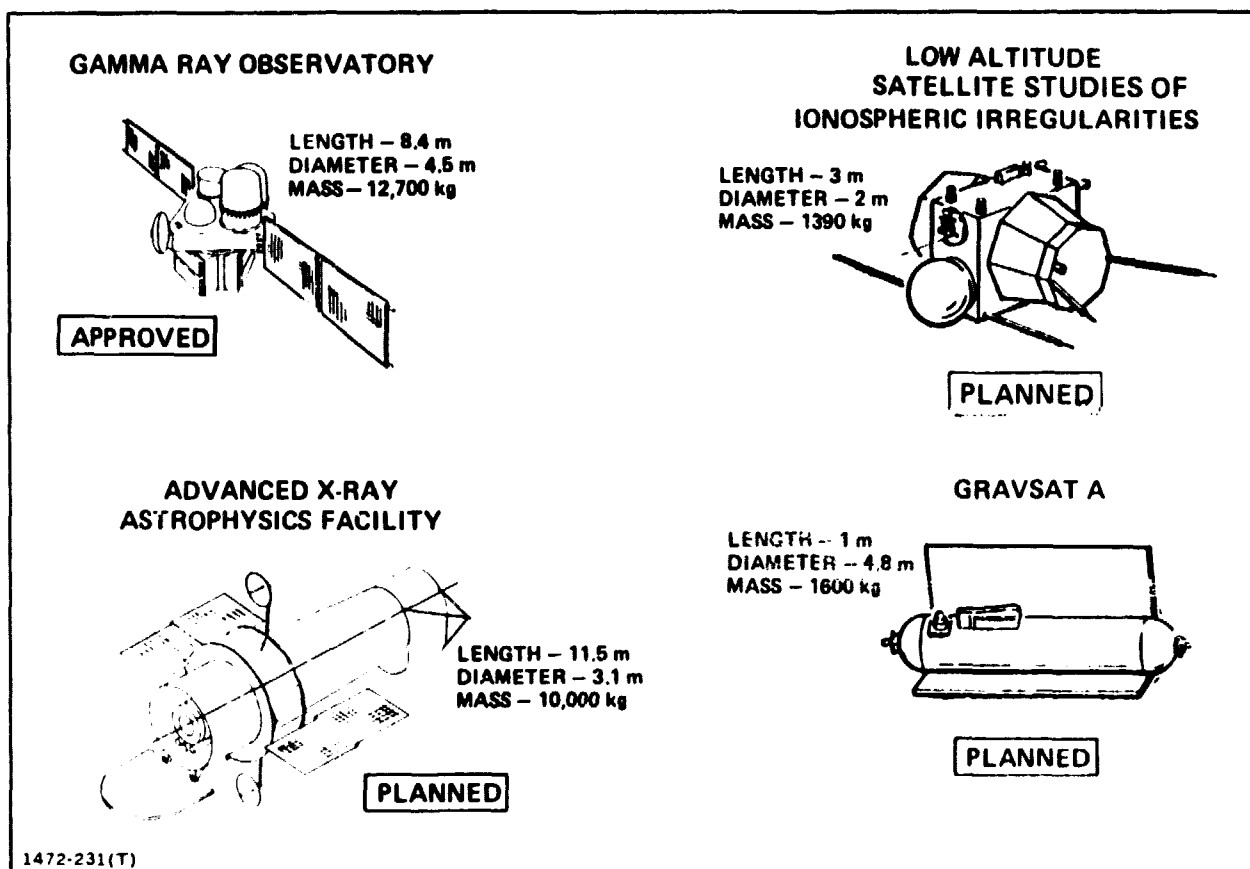
1472-229(T)

Fig. 3-2 Reference Satellites

DELIVERY & REVISIT SCHEDULES											
DIRECT DELIVERY SATELLITES	CAT.	YEAR									
		'84	'85	'86	'87	'88	'89	'90	'91	'92	'93
GAMMA-RAY OBSERVATORY	A	▲	○	▼							
LASSII	P			▲▼	▲▼	▲▼	▲▼				
GRAVSAT A	P		▲					▲			
ADVANCED X-RAY ASTROPHYSICS FACIL	P					▲	●	●	▼	▲	○
▲ DEPLOYMENT						○ REVISIT (ASSUMED)					
● REVISIT (PLANNED)						▼ RETURN (ASSUMED)					
▼ RETURN (PLANNED)											

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Fig. 3-3 Servicing Events for Reference Satellites — Direct Delivery/Servicing



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Fig. 3-4 Reference Satellites — Direct Delivery/Servicing

Figure 3-5 identifies the five reference satellites for the LEO/Propulsion class and the two satellites for the GEO class. Their corresponding delivery/revisit schedules are also shown. Figures 3-6 and 3-7 illustrate the spacecraft configurations.

Reference satellite selections have favored the Approved/Planned (A/P) category, but also reflect the Candidate (C) category in the late 1980s. The reason for this was to appropriately cover the spectrum of potential satellite programs in the 1980s decade when considerable servicing needs are projected.

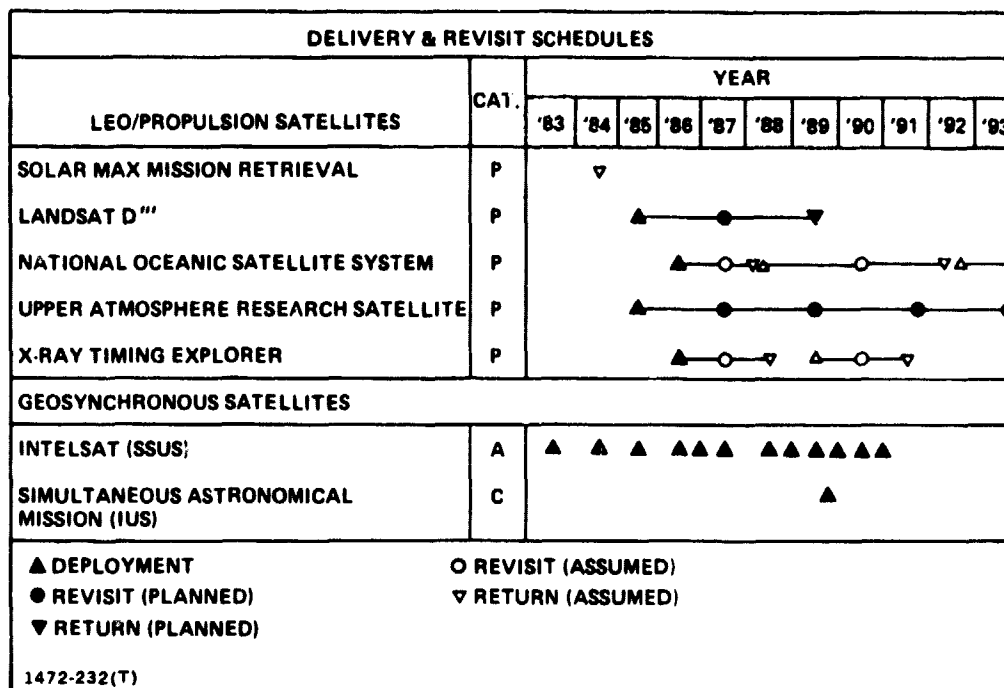


Fig. 3-5 Servicing Events for Reference Satellites — LEO/Propulsion & Geosynchronous

Figure 3-8 illustrates configurations of the Orbital Debris reference satellites. In general, little information exists regarding the characteristics of inactive satellites and debris. We have selected the Orbiting Astronomical Observatory (OAO), however, since it is a satellite with which Grumman is familiar. In addition, it appears in the altitude band and radar cross-section areas with highest population/collision potential. A representative large debris candidate was also selected to exercise concepts for controlled de-orbit of such elements from potentially "problem" orbits/altitudes.



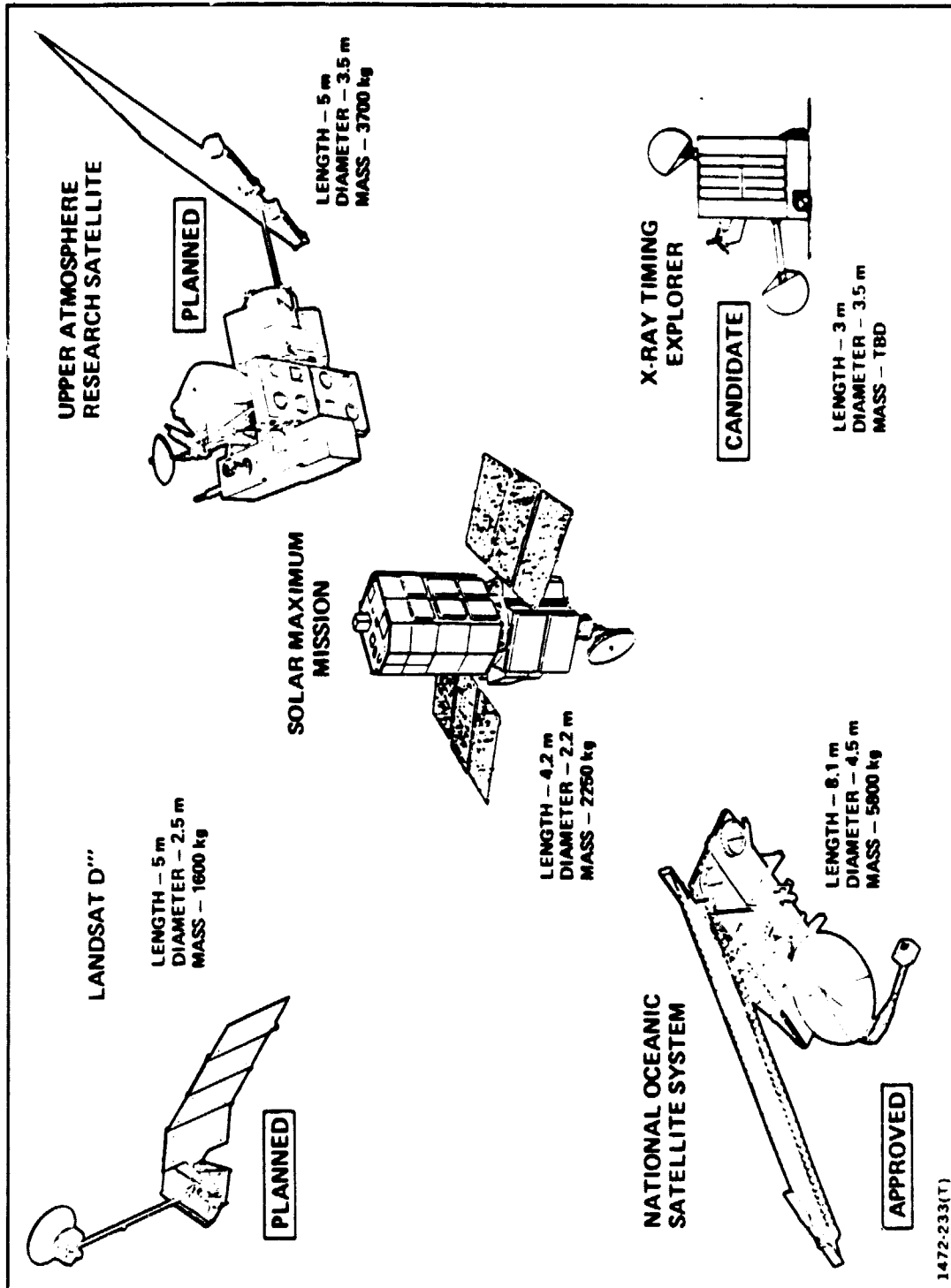


Fig. 3-6 Reference Satellites - LEO/Propulsion

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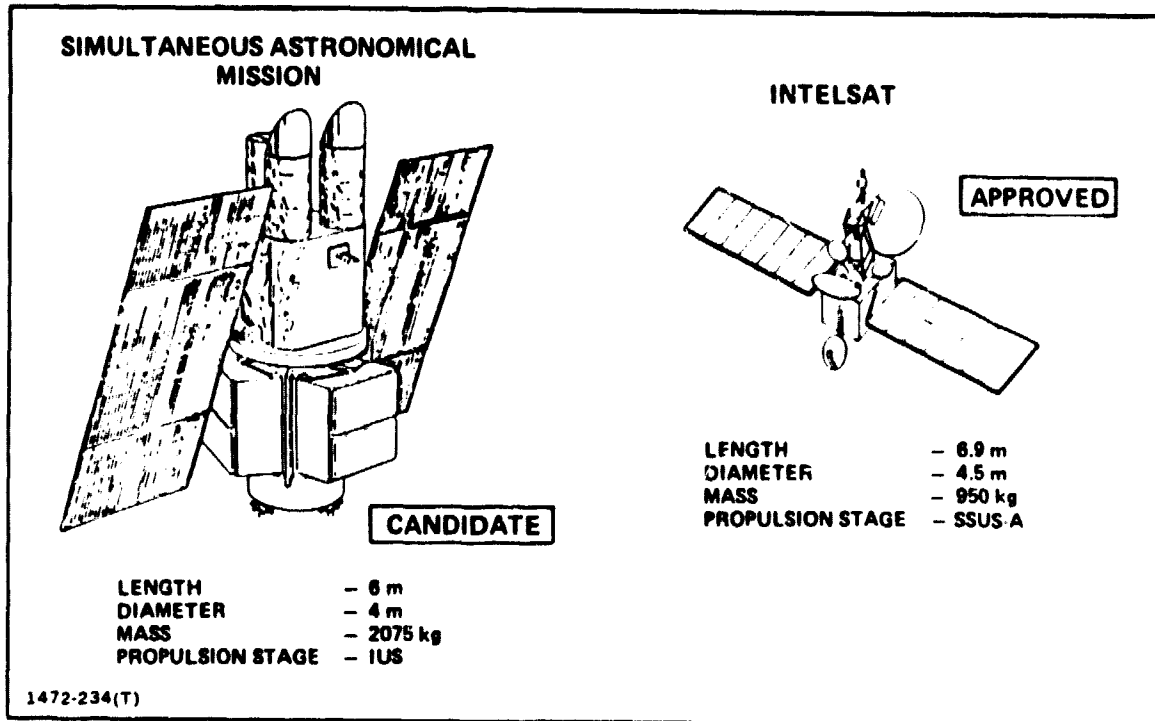


Fig. 3-7 Reference Satellites - Geosynchronous

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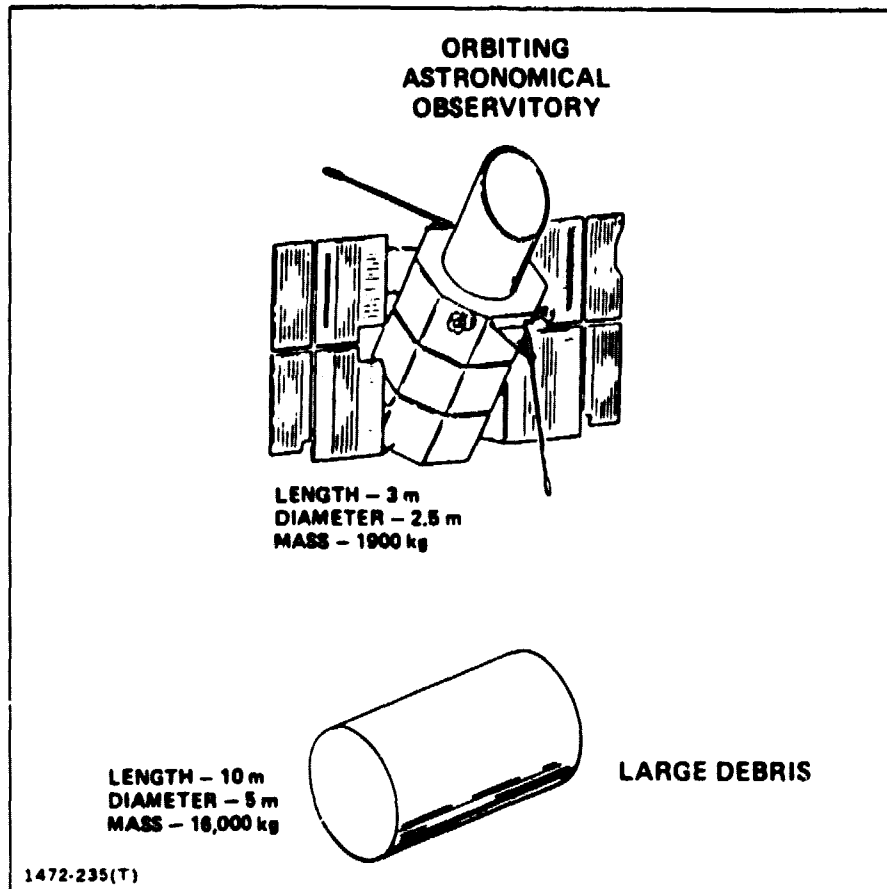


Fig. 3-8 Reference Satellites - Orbital Debris